SILICON CHIP

JUNE 2020
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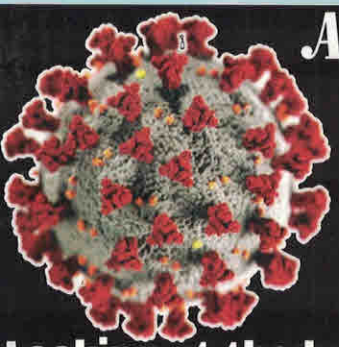

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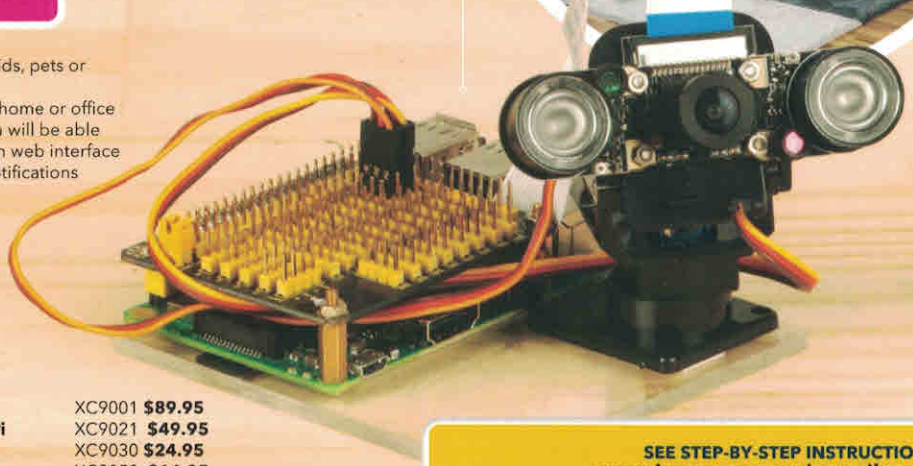

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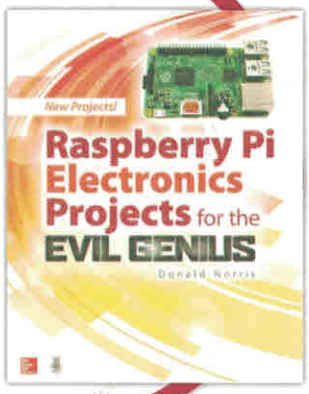

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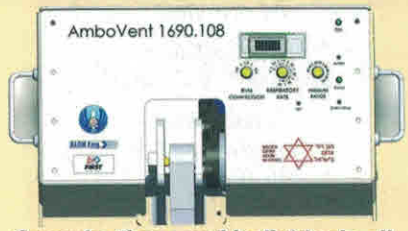

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Editorial Viewpoint

National Broadband Not-work?

Late last year, a person rang me at home to say that the NBN would be available in my area "soon" (I'd heard that one before...). Anyway, they said if I was happy to stay with my current internet provider, they'd send me the NBN equipment as soon as my house was connected. As promised, it arrived in early March.

This was around the time that the government was advising us to work from home to prevent the spread of COVID-19, so I didn't want to be without internet. They told me to disconnect all my ADSL equipment one evening and plug in the NBN gear, and I should be up and running the next day.

I did what they asked, but the next morning, I had no internet. I rang their support line and the helpful staff member spent a while troubleshooting it with me before concluding there was something wrong with our connection. They would have to send a technician out. That would take about ten days. Ugh!

So I had to work from home using a very slow and expensive 4G connection via my phone. When the NBN technician turned up, he seemed to know what he was doing and told me (I don't remember his exact words): "the ports were mislabelled and so you were connected to the wrong port but I've fixed that."

It did not fill me with confidence that the NBN cable installers didn't label the ports correctly. But at least he'd fixed that problem. However, I still had no connection.

After more investigations, he came back in with a bit of a sheepish look and told me: "The fibre's no good. I'm going to have to get someone to come back and fix it." And the first available appointment was more than a week away. Ugh again!

So, it appears that the people who ran the NBN optic fibre didn't actually test it to see whether it worked before reporting that they'd done their job. That's really unacceptable.

Anyway, they did come back and fix it as promised. By then, I'd been without internet for around three weeks. But finally, the NBN was working! It worked for a whole eight days. Then suddenly it just dropped out.

So I rang the support line again. They did a bit of checking and told me "the NBN system says that your connection has been cancelled." Excuse me, what? Why? And by whom? "It doesn't say why. We'll have to reconnect you from scratch." How long would this take? "A few days."

It took more than three weeks.

The request had to go from my ISP to NBN Co and then onto the contractor, who rejected it because I "had no phone line". It then had to go back to NBN Co and back to my ISP, who had to ask for my phone line to be reinstalled, then when that was fixed, they started the whole process again.

Apparently, the contractor for my area is based in the Philippines so this was a slow process. Why is part of Australia's National Broadband Network run out of the Philippines? That makes no sense to me.

Finally, in early May, my NBN connection was working again. So for March and April, while I was quarantined at home most days, my NBN connection worked for a whole eight days.

I never received any explanation as to why my phone line was cancelled (I *certainly* didn't request it!). Will that happen again? Who knows? Apparently, there are no processes in place to stop accidental cancellation.

What sort of crazy system is this that we're being forced onto? I've had ADSL for nearly 20 years and never had any problems like this. It isn't just me, either. Another SILICON CHIP staff member had the NBN crew run cable to most of the houses in his street, including both of his neighbours . . . but not his. He had to contact them and they eventually came back and hooked him up.

You have to wonder who thought it was a good idea to give national responsibility for fixed line internet to such a disorganised group of people.

Nicholas Vinen

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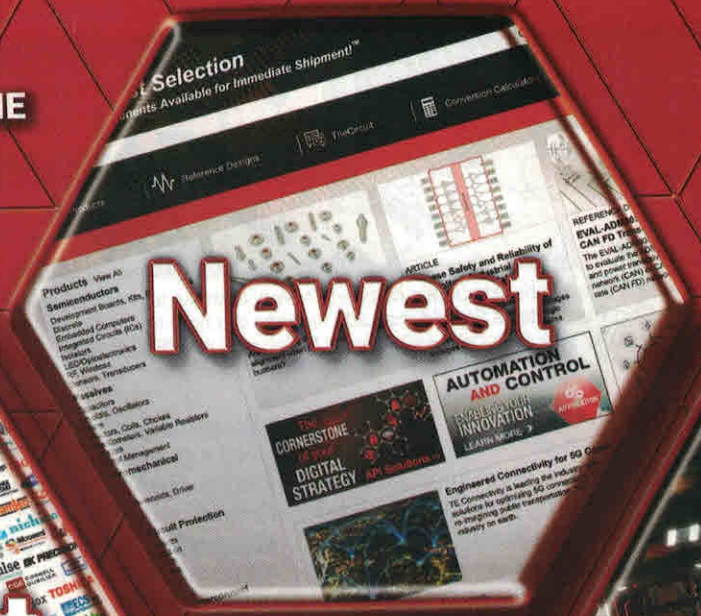

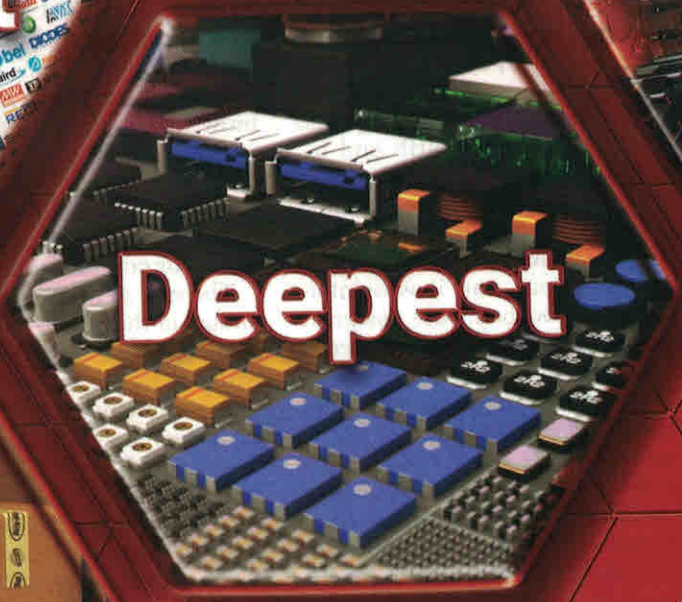

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Comments on PDFs and stabilising fuel

I would like to give some positive feedback regarding your PDFs on USB and to download (siliconchip.com.au/shop/digital_pdfs). I have been a long time reader of SILICON CHIP and I have all the issues back until the start of 1994. The offer of a 5-year plus block at $100 to get the issues I missed represented good value.

It was interesting to read the first issue and publisher's letter by Leo Simpson regarding the birth and intent of the magazine. I had forgotten about cigarette and alcohol advertising which was around in the 1980s.

I enjoyed the many and varied projects of yesteryear, and it was interesting to see how they were designed before the common use of microcontrollers. They used logic gates and specialised ICs to perform tasks that micros can easily do today.

Your comments in the May 2020 editorial regarding the back issues are valid reasons to check them out also.

As promised by Leo Simpson back then, the magazine has continuously improved its quality. I now have the back issues to provide both great nostalgic value and enjoyable reading.

I would also like to comment on your article about being prepared for power outages. I have a generator similar to the Jaycar model you described, plus a plastic Jerry can with 20 litres of emergency fuel.

The way I keep this long term is a fuel additive called STA-BIL. You can get this at Repco, Supercheap, Autobarn etc. It easily keeps the fuel fresh for 12 months in my experience; the website claims 2 years.

Geoff Coppa,
Toormina, NSW.

Large flywheels deserve respect

Dr David Maddison's article on Grid-scale Energy Storage (April 2020; siliconchip.com.au/Article/13801) joins a growing list of his articles that I enjoy. His GNSS feature ("How does Satnav work?" – November 2019; siliconchip.com.au/Article/12083) is required reading for spatial science professionals.

Flywheel storage has been an integral part of critical UPS systems. The description of DRUPS engagement reminds me of a funny, salutary story.

The Civil Aviation Authority (CAA) built a new Air Traffic Services (ATS) building at Tullamarine in 1970. The critical component is continuous uninterrupted power, so they put a DRUPS in the technical building. Gotta test it for commissioning.

The way a DRUPS starts on a power outage is that the power cut initiates the diesel engine starter motor. The flywheel is busily driving the alternator to maintain supply. When the diesel is up to speed and the revs synched then the magnetic clutch is engaged. And all is well.

However, the brave techs said, "what if the starter fails?" The answer, "drop the clutch, that'll get her going." So they tried that. And then spent a week getting bits of the engine out of the walls and floor.

Then they had to install a new engine. You can't go from naught to 1500 revs in a microsecond with a 10-tonne flywheel in command!

John Walker,
Salter Point, WA.

Home security systems and the NBN

You may recall that earlier this year I raised the issue of the NBN (via a Telstra modem) being unable to support the autodialler for my Home Security System. All the Telstra literature said it wouldn't work. Well, it does!

I spoke with a Telstra techie recently, and he said he had heard of that comment, but as far as he knew, the reason Telstra said that was because it won't work if the electrical power to the house is cut.

With underground power that is a rare event nowadays, but a robber could easily switch off the power at my accessible main breaker box (I should install the standard Western Power lock).

Within an hour of the NBN hybrid coax cable (HFC) being connected via my old Foxtel coax, the dial tone on the copper pair to the exchange disappeared, but the 48V remained.

I progressively connected one DECT phone to the phone socket on the back of the Telstra modem, then a second, then finally the security system autodialler. I had to reprogram that from pulse-dialling to DTMF, then everything worked. By the way, this latest-model modem has a 4G backup, so the loss of NBN connectivity is not fatal.

The end result is that the security system works fine and I have avoided the considerable cost and ongoing complexity of a new security controller box and attached 3G independent dialler. I hear 3G is on its way out, so I would then need to have bought yet another "box" served by 4G – endless cost and hassle...

David Kitson,
Claremont, WA.

Updated bike alarm project wanted

I recently purchased an electric bike, an XDS E-VOLVE GS, which included a lengthy investigation into anti-theft devices. I think I will need a good alarm system, along with a chain or similar way to tie up the bike and wheels. But no alarm system on the market tickled my fancy.

Could you design a self-contained alarm system which fits in a diecast aluminium box that can be mounted on the handlebars or seat post, turned on and off with a key switch, and with a display of bright coloured LEDs

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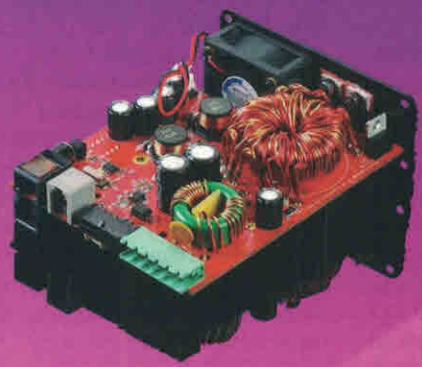

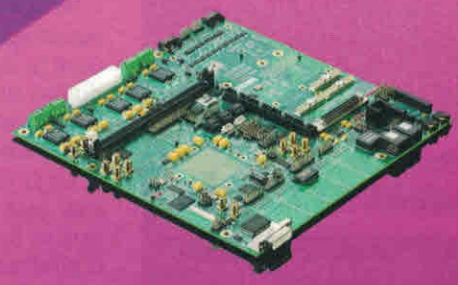

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around its perimeter when switched on, to act as a deterrent?

When moving a bike, the handlebars are often the first part to be grabbed and moved, so I think that would be the best place to mount it. There are bars available that can be used to attach accessories to the handlebars.

An array of mercury switches could detect the state (angle) that the bike is parked at and trigger an alarm when the state of the mercury switches are changed. It could give a short bleep (or recorded message like "move away from the bike") if bumped or moved momentarily, and emit a screeching noise with flashing lights if that movement is maintained.

It could run from alkaline, lithium or rechargeable lithium batteries, to allow people to adapt it to suit their particular situation or budget.

What do you think? I'm sure it would be popular with the number of bicycles and e-bikes on the increase.

Jacob Westerhoff,
via email.

Response: that is a good idea, although we think that a MEMS accelerometer/gyroscope module would be better for detecting motion than an array of mercury switches. We are looking into what would be involved in producing such a project, although we can't promise that it will come to fruition at this stage.

Digital equaliser wanted

It's good to see a rotary potentiometer based audio equaliser that is practical in your April 2020 issue (siliconchip.com.au/Article/13804). However, I would like to see an all-digital-logic controlled audio equaliser in hardware! Using say 4066 quad bilateral switch ICs instead of potentiometers. Or maybe you could use optocouplers or photoresistor couplers.

A digital logic controlled audio equaliser would have all manner of uses in say a similar way to analog-to-digital converter circuits. Compressor limiter gates, microcontroller adding hundreds of presets, remote control etc.

Or is there a software solution that lets one use a powerful microcontroller to equalise many channels of digital audio at the same time, before converting the combined audio back to analog?

Digital control would give audio equaliser project more uses, maybe by adding a graphic equaliser LCD screen with up/down buttons on each EQ band.

I'd also like to comment on your article on grid-scale energy storage in the same issue. They look like Rube Goldberg machines *(Editor's note: readers would probably be more familiar with the term "Heath Robinson" machines).*

John Crowhurst,
Mitchell Park, SA.

Response: we actually have been working on a digitally controlled preamp with bass and treble controls, but there have been delays. We still hope to publish that design. It seems unlikely that 4066 switches could be used to replace pots; they would have to be switched at frequencies well above audio with very precise control to get good results.

Digital pots are a much easier way to replace regular pots (as you say, there are optical devices too, but they usually give much less precise control). Using quad digital pots, a mono 8-band equaliser can be done with just two chips, or four for stereo.

The problem with the digital pots approach is that they generally only support a signal swing of 0-5V which is one-sixth that of the typical -15V to +15V swing possible with standard op amps and pots. That translates into a loss of roughly 15.5dB of signal-to-noise ratio and headroom. Still, it's "good enough" for basic use.

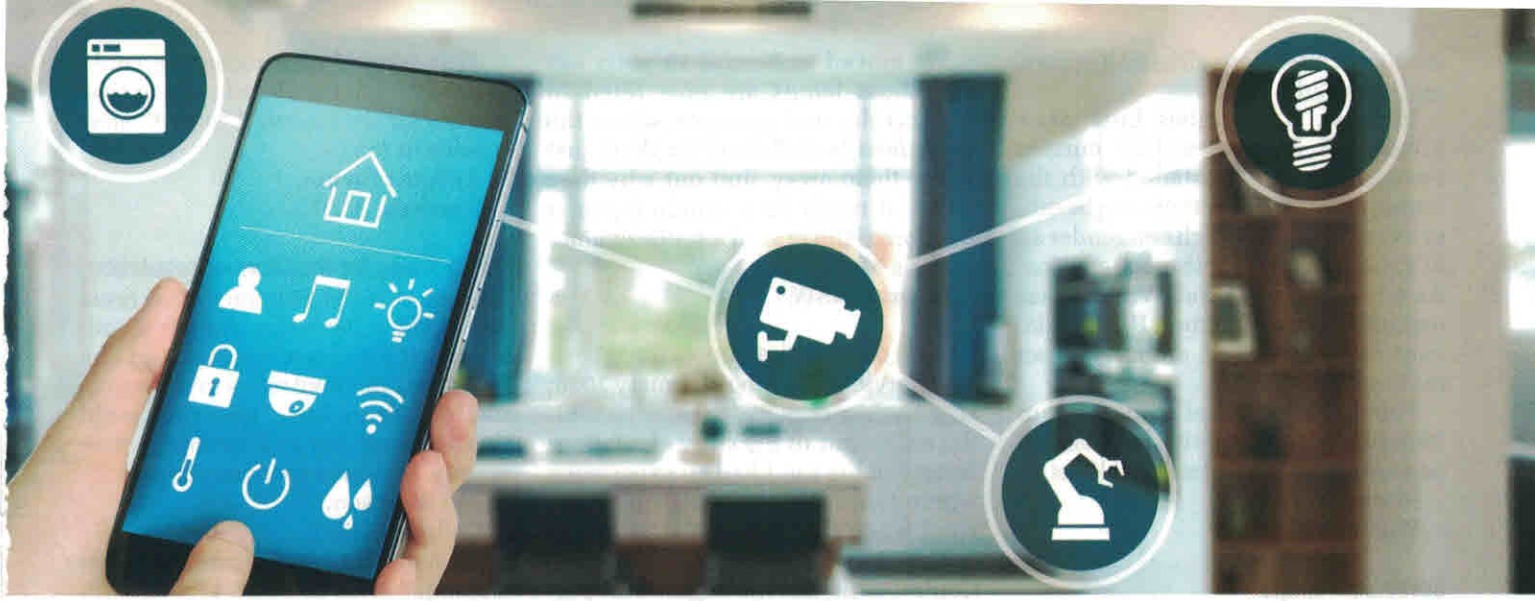
Equalisation can definitely all be done in software, but you need an outstanding quality codec to avoid distortion from the A/D and D/A conversions. That's essentially what the DSP Active Crossover and 8-channel Parametric Equaliser from our June and July 2019 issues does (siliconchip.com.au/Series/335).

We also have a very high-quality codec project coming up later this year which would be used as an equaliser in conjunction with a PC.

Many of the Grid-scale Energy Storage solutions are indeed "pie in the sky" ideas. They're interesting from an engineering perspective but not terribly practical, especially when compared to the normal and well-proven solution of pumped hydro. Still, some of the devices we described in that article are actually in use, so they must have some utility.

Unsafe 'safety switches'

I came across the following page while browsing the Energy Safe Victoria site and thought I should bring



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it to your attention: siliconchip.com.au/link/ab2d

In brief, it describes how some household RCDs (residual current devices) could be installed with the wrong orientation, or there can be other external faults which can render an RCD useless, leading to electrocution. As a result, Energy Safe Victoria has banned the use of certain RCDs in favour of others which are not subject to these flaws.

There is a fair bit of additional information at that web site, both on that page and on other pages that it links to.

Marcus Chick,
Wangaratta, Vic.

Some LED lamps have insufficient cooling

I read the "LED lamp repair" contribution by L.B. of Mittagong in Serviceman's Log, May 2020 with interest. I bought 24 LED lamps just when they came on the market here in Australia. I got them from a shop in Auburn, and the salesman gave me a very enthusiastic run down on all things LED lighting, including a prediction that they might stock LED versions of neon lamps soon!

The type I bought was 230V 5W GU10. I was impressed with the 10,000+ hours life sales pitch. But it wasn't very many hours of use before the first one failed. Then a second and third one. So I wanted to know if there was anything specific which caused them to fail. The only way I could find to open one was to hacksaw the barrel off. It looked like ceramic but turned out to be plastic.

The cause of the failure was obvious: a black resistor at the end of the circuit board — the same with the other two. One had heated so much that the circuit board was destroyed, as were the nearby components.

I opened a good one the same way and was able to determine the resistor value. So I soldered new ones to the remaining two lamps, and they came to life again. I used superglue to reattach the barrels, and they are still together.

My view was that because the electronics were in such a small confined space, with no heatsink, they had to cook. I ended up drilling small holes into the barrels of all the lamps I had for air circulation. Some 20-odd-years later, they all still work. Unfortunately, they are not as bright as the currently available types.

We moved to Bowral 10 years ago and those lamps are now fitted in the corridor and sunroom where the brightness is sufficient. So don't just throw them away, find out why they failed; it might be a simple repair, a fraction of the cost of a replacement.

Hans Moll,
Bowral, NSW.

Finding car electrical problems

In Serviceman's Log (February 2020; siliconchip.com.au/Article/12339), the editor put in his story of a failing battery in his car. I had an experience where the cruise control would not work when the car warmed up.

This is a function in the Engine Control Unit, but the engine still performed OK. The service mechanic replaced springs and contacts in the steering wheel and other bits before replacing the battery, which ultimately fixed the problem. All other operations of the car, including starting, were working fine.

I expect the performance of the battery is becoming more critical with more electronics being essential for the car to run. I recently come across the "Century Battery Monitor": www.centurybatteries.com.au/products/battery-monitoring

As shown below, this is a small box that connects across the battery and logs the voltage. It can record up to 31 readings and then uploads this data to an app on your smartphone via Bluetooth. The app then gives you a plot of the performance of the battery, and can do other analysis of the battery performance with the operation of the car.

This type of data recording could well highlight the electric power conditions for the essential "smart" electronics in the car.

Richard Blyton,
Kambah, ACT.

Using Triacs for transformer regulation

I just read the February 2020 issue and again, it has a fine line-up of projects. Just a comment on Mailbag: The letter from Bill Pool refers to mains regulation using a Triac. John Clarke did this years ago for a 12.6V 40A power supply, if I remember correctly.

Leo Simpson,
Collaroy, NSW.

Comment: you are right; he used that technique in the 13.5V 25A Power Supply for Transceivers, May & June 1991 (siliconchip.com.au/Series/220). That was an impressive project. These older issues are now available as PDFs, either purchased individually as online issues or as part of our PDFs on USB offer (siliconchip.com.au/shop/digital_pdfs).

DAB+ retransmission in tunnels is possible

I read your comment on my letter in the January 2020 issue ("The future of radio in Australia", page 4). All Australian mainland capital cities have tunnel systems. In road tunnels, it is common to install a radio repeater system so that existing car radios keep working. These also can broadcast warnings and instructions to the drivers in emergencies.

These systems receive all the local broadcasts, demodulate the signals

Finding car electrical problems

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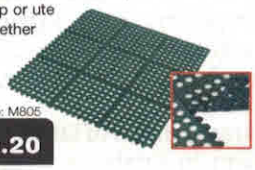

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and then retransmit them within the tunnel on their original frequency. If there is an emergency, they switch the transmitter input from the receiver to a microphone in the tunnel control room.

In Norway, Paneda and Digidia have installed DAB+ break-in systems in more than 233 road tunnels. These systems have a receiver for each local DAB+ signal. The data output of each receiver is then fed to a low-power DAB+ transmitter on the original channel. The signal is radiated along a leaky RF cable along the length of the tunnel.

At the same time, the received data is also used to synchronise a DAB+ encoder. A GPS frequency reference is used to ensure that the regenerated transmission frequency and the data frequency are identical to prevent sound breakup at the tunnel entrances.

When there is an emergency, there is a data switch from the received data to the tunnel controller's encoder. The tunnel controller can then issue warnings and instructions on every program stream through the car radios to all drivers in the tunnel.

I would also like to point out that the www.myswitch.gov.au website shows the need for TV black spot translators in Australia, and DAB+ suffers from similar coverage problems, also needing repeaters at the same sites. It shows that Brisbane needs eight sites, Sydney one, Canberra three, Melbourne 10, Adelaide 11, Perth four, Hobart seven and Darwin two.

Each site requires a pair of transmitters of 500W effective radiating power or less, except in Brisbane, Sydney and Melbourne where three are required at each site.

Also, Sydney is the only city which has a backup transmitter in case of failure or to enable maintenance to be performed. All other capital cities need one high-power DAB+ backup transmitter which can be shared between broadcasters.

In Darwin, all radio and TV broadcasts except ABC Radio National (AM) are radiated from the same single tower, making the city vulnerable to a communications blackout during cyclones. Most AM and FM broadcasters have a backup transmitter because dead air costs commercial broadcasters money!

Alan Hughes,
Hamersley, WA.

AM/FM superior to DAB+ in emergencies

On 14 February 2020, the Sydney Morning Herald reported regional and rural commercial radio stations want the Federal Government to spend $80 million on DAB+ radio transmitters to facilitate broadcasting emergency information to communities (siliconchip.com.au/link/ab2c).

The proposal states that commercial stations could supplement the ABC's role in providing critical information to listeners with the ability of DAB+ to add secondary audio and data channels. The commercial broadcasters claim this will provide enhanced information.

The introduction of DAB+ radio to regional and rural areas will certainly provide better program choice. But DAB+ broadcasting cannot be relied upon in a bushfire emergency. DAB+ transmitters are generally co-sited with TV transmission facilities, often on top of the tallest mountain in the district. In many regional and rural areas, these mountains are covered in and surrounded by dense bush.

For example, in the case of Batemans Bay, the transmit-

ter is located on Mt Wandera in a State forest, which was recently devastated by the Clyde Mountain bushfire.

This destroyed the shared TV & FM transmission tower as well as overhead power lines to the site, forcing all services off-air just as the fire approached populous areas and the community's emergency information need was at its greatest.

Residents of Batemans Bay and Moruya were still able to receive emergency information from the ABC via FM radio from Ulladulla or AM radio from Bega. There was a high level of static and noise, but the stations could still be heard. This is generally not possible for DAB+ broadcasts due to the 'digital cliff' effect.

Another problem is radio battery life. The fires across the South Coast destroyed critical electricity distribution infrastructure. Nearly all of the region, from Nowra to Eden, was blacked out for a couple of days. Batemans Bay was without power for a week, and some communities were blacked out for a month or more.

During this time, the fires were still raging and the ABC recommended that people used portable, battery-powered radios for updates on the danger.

DAB+ radios are much more demanding on power. Their batteries typically last for eight or so hours of listening, compared to more than 100 hours from even a small portable AM/FM receiver using standard AA batteries, which most people would have stocks of.

My suggestion is that, in addition to providing regional and rural DAB+ broadcasts, regional and rural AM stations should be moved to the FM band, freeing up the existing AM transmitters for emergency broadcasts. They can be powered down when not needed. Ideally, the AM transmitter power should be increased to achieve clear reception in all key areas.

The Federal Government spending $80 million on DAB+ on the pretext that it is a robust way of keeping communities informed in times of emergency is a folly, and rent-seeking by the commercial radio industry.

Tim Herne,
Batemans Bay.

Warning about air quality monitor modules

After purchasing a CCS811/HDC1080 module from an Australian seller on eBay for the Indoor Air Quality Monitor (February 2020; siliconchip.com.au/Article/12337), I found all was not as it should be. The seller's photo clearly showed part numbers and photos with both sensors. However, I received a module minus the temperature/humidity sensor.

The sealed bag the product came in is labelled for the correct part, but unfortunately, the part supplied does not match. To the credit of the seller, he offered to supply me with the correct part or refund my purchase. As we all know, it's a pain having to wait! Buyer beware.

Phil Jenner,
Adelaide, SA.

Several project suggestions

1) Power companies now offer compensation if one experiences an excessive number of mains interruptions, but it takes quite an effort to keep track of such breaks.

How about a project to build a power line interruption logger? It could log the time and date of the interruptions and their durations. It could also log over/under-voltage conditions.

Of course, it would need a battery backup, or at least a low-power microcontroller with a power source (a supercap?) that could keep the monitoring going during a power outage.

2) All cable testers measure continuity, but how about one that also detects short breaks in continuity as you wriggle a suspicious cable? It could be based on a pulse stretcher.

3) A talking and/or display clock that gives the time as we say it. For example, quarter to eight, 17 past five, 28 to nine, half past six etc.

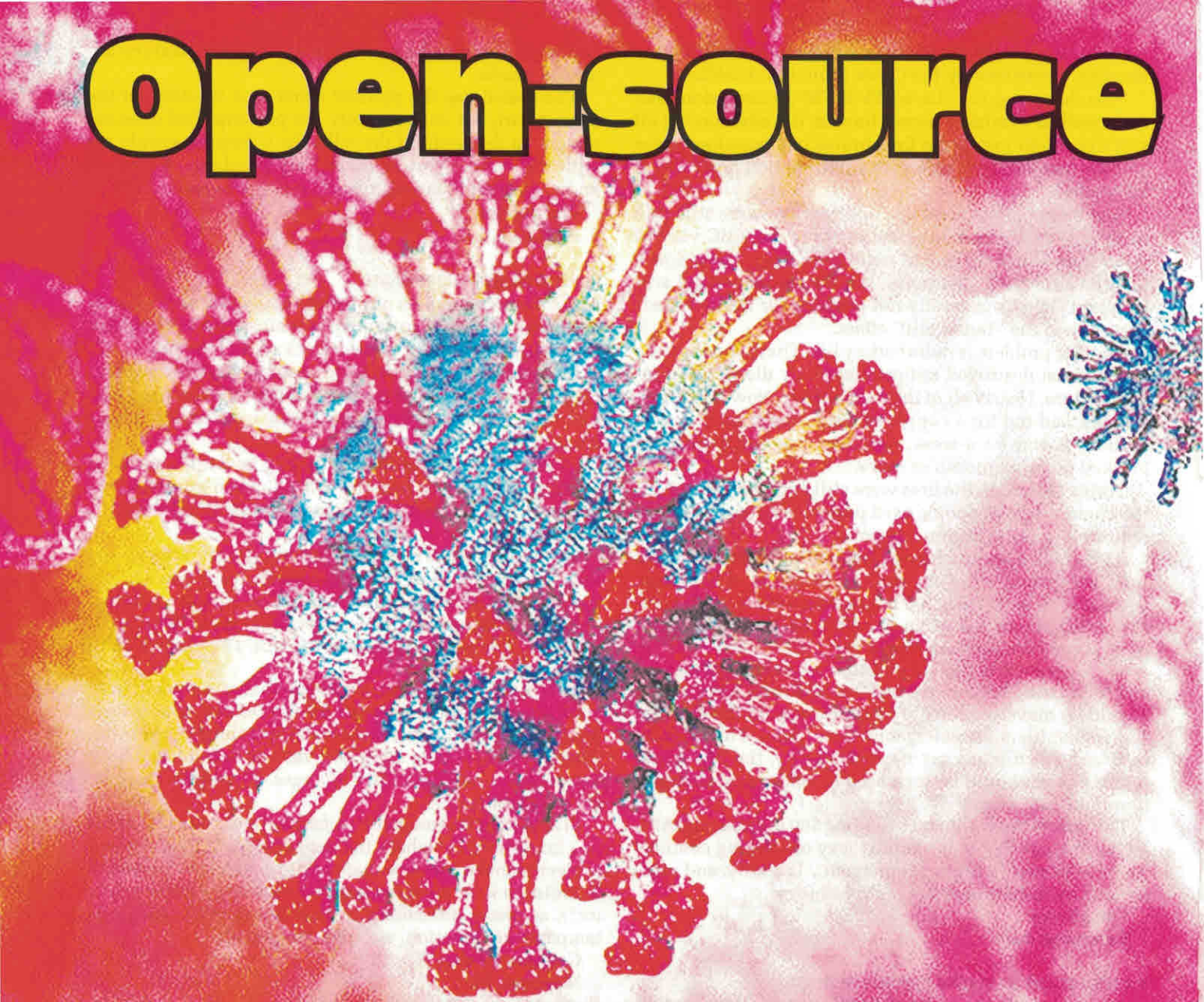
4) A unit with a humidity sensor that automatically controls a bathroom exhaust fan, switching it on as the humidity suddenly increases at the beginning of a shower. There could even be a kitchen variant that detects both temperature and humidity changes to operate an overstove rangehood.

5) A talking thermometer. A familiar question one hears in a household is "what's the temperature?". How about a project to make a device that announces the temperature? It could do it on a timed basis, on request (whistle detector?), at preset milestones or increments, at a change in temperature direction, at rapid changes etc.

Graham Goeby,
Macleod, Vic.

Response: we published an alphanumeric clock in the November 1994 issue (siliconchip.com.au/Article/5211) and we have a new clock using a similar concept coming up in the July 2020 issue. The other suggestions are good and we will take a look at them. SC

Open-source



When COVID-19 started spreading around the world in early 2020 (or possibly late 2019; this is not yet certain), one of the big concerns was that there wouldn't be enough ventilators in hospitals to treat patients who had trouble breathing. Many companies and individuals set about trying to solve this problem; many of them had no medical background, but nonetheless came up with clever solutions. This article describes some of the more interesting ones.

by Dr David Maddison

Ventilators

The media has been awash with reports about COVID-19 for the last several months, so we aren't going to cover basic facts about the disease, many of which are still not known as we write this.

Nor are we going to get into the medical side of the issue, eg, which patients should be placed on ventilators or how much it helps. There is some controversy over that point.

We aren't medical experts (Dr Maddison is a different kind of doctor). So we will leave such discussions up to the professionals.

But one thing that is clear to us is that a great many people and organisations rushed to help when it was widely reported in the news (rightly or not) that there would be a major shortage of ventilators.

Many factories which were previously turning out motor vehicles or other appliances have been converted to produce medical supplies, including ventilators, in a remarkably short time.

Some medical manufacturers have outsourced production to other manufacturing enterprises such as car companies, akin to the way many items were produced during wartime, when the usual manufacturers could not satisfy demand.

Of course, medical manufacturers who were already producing ventilators have also done what they can to ramp up their own production.

One company, Medtronic, has even 'open-sourced' all the documentation for one ventilator design, free of charge, to anyone who wants to produce it. Others in the "maker" community have rushed to start projects design and produce their own ventilators.

This article is mainly about that last group, ie, open-source hardware and software designed by people who share their information and designs without monetary compensation. Note that, at the time of writing, this area was developing rapidly and so there may be important advances made between then and when you are reading this.

If you want to help out, you may be able to find a project to which you can contribute. Given the large number of existing projects, that is probably more helpful than starting your own.

If you're a keen maker, you might also consider becoming involved in developing personal protective equipment (PPE) of various kinds. One example described here is a Powered Air Purifying Respirator (PAPR). Another might be simple and effective masks to wear on the street.

Given that there are a vast number of projects, this article cannot possibly cover all of them all. Therefore, we will look at a few that show a sampling of the type of work being done and will provide a list of the remaining projects which while worthy. You can research them yourselves if interested.

Ventilator reliability

While the basic engineering of these devices is relatively simple, they are safety-critical devices, as failure can definitely lead to a patient death if they are not attended to by medical staff in a short time. The general principles of "reliability engineering" as they apply to medical devices should be taken into account in their design and manufacture. Many of the projects described here are at a very early stage of development, and not yet ready for the clinical environment.

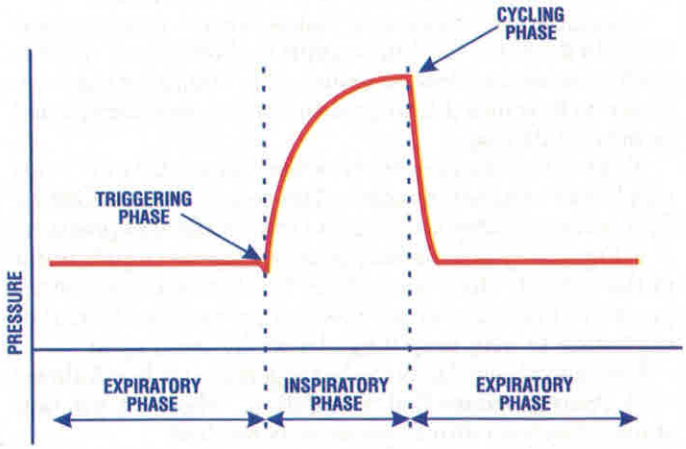


Fig.1: the four phases of mechanical ventilation. ***Source: Alex Yartsev.***

What is mechanical ventilation?

Mechanical ventilation involves introducing air, with or without extra oxygen, into the patient's lungs at an elevated pressure with the initiation of breathing cycles caused by either the machine or the patient, or a combination of both. Breathing is maintained by ventilation until the person's body heals itself and they can again breathe independently.

Note we are discussing positive pressure ventilation. Negative pressure ventilation also exists, such as the "iron lung" and similar devices. Those are mostly used for those with neuromuscular disorders.

Mechanical ventilation is non-invasive if air pressure is applied via some type of facial mask. It is invasive if air is introduced via the mouth or nose with an endotracheal tube, or through the skin into the trachea via a tracheostomy tube. For invasive ventilation, which is required for more severe cases, the patient has to be sedated and/or paralysed.

For non-invasive ventilation via a facial mask, it is possible to use relatively simple machines such as typically used to treat sleep apnea at home. These are either **CPAP** (Continuous Positive Airway Pressure) or **BiPAP** (BiLevel Positive Airway Pressure) machines.

In CPAP, positive air pressure is delivered continuously. In BiPAP, one pressure is maintained during inhalation, but a lesser pressure is applied during exhalation. This bi-level pressure enables more air to be exchanged than with CPAP. CPAP and BiPAP modes are also available on commercial hospital-type ventilators.

If there is a lack of hospital-type ventilators, treatment by

CPAP and BiPAP is suitable for less seriously ill patients, who can spontaneously breathe but need some assistance. Invasive mechanical ventilation is required for more seriously ill patients.

Mechanical ventilators have four phases (see Fig.1):

1) Initiation, controlled by a set trigger variable such as time, airflow or pressure, with the breath initiated either by the machine or the patient's attempt to breathe.

2) Inspiratory (inhalation) phase, when a volume of gas starts to flow into the lungs controlled by a limit variable such as pressure, flow or volume. Eg, 500mL of gas is allowed to flow into the lungs with limited pressure applied to prevent damage.

3) "cycling", the moment between when inhalation stops and before exhalation begins. The period is controlled by the cycling variable according to time, airflow or pressure.

4) Expiratory (exhalation) phase with passive airflow out of the patient, often using PEEP (positive end-expiratory pressure) that maintains a positive pressure at the end of expiration to help keep lung alveoli (air sacs) open.

Mechanical ventilators can be triggered to cycle as follows:

1) Pressure-controlled ventilation, where inspiration stops when a set airway pressure is reached.

2) Volume-controlled ventilation, where a set "tidal" volume of air is delivered to the lungs and pressure can vary, but a maximum pressure is set to avoid lung damage (barotrauma).

3) Time-cycled ventilation, where the tidal volume (breath volume) is controlled by setting the flow rate and inspiration time.

4) Flow-cycled ventilation, where inspiration is terminated when the flow rate drops to a set level.

According to the American Heart Association (AHA), the primary modes of ventilation for COVID-19 patients have a set number of breaths per minute and are:

1) Assist Control (AC), where the patient can initiate breaths, but the machine can also do so at the set rate if the patient does not breathe by themselves. The same tidal volume is delivered for every inspiration.

2) Synchronised Intermittent Mandatory Ventilation (SIMV), whereby a mandatory breath from the machine is delivered with a set tidal volume plus additional breaths by the patient above the set rate are supported.

Secondary modes are:

3) Airway pressure release ventilation (APRV), with a positive airway pressure and timed release of that pressure.

4) Pressure regulated volume control (PRVC), a pressure-controlled mode with a set tidal volume and the inspiratory pressure changing from breath to breath, to achieve the targeted volume.

Helpful Engineering

There was a recent government-sponsored gathering of amateur engineers, held in Germany over 20-22 March 2020.

"Der Hackathon Der Bundesregierung" (siliconchip.com.au/link/ab18) was dedicated to COVID-19 related projects, with 42,869 people signing up.

Out of that meeting arose the Helpful Engineering organisation (www.helpfulengineering.org), which was founded to help people with the COVID-19 crisis. You can join as a volunteer. It currently has over 3400 members such as engineers, developers, doctors and scientists working on over 35 projects.

The object of these treatments is to get enough air/oxygen into the lungs to keep the patient alive but not to overstress infected tissue, possibly causing it to rupture (barotrauma). As the lungs become more diseased, they become less elastic and so more pressure is required to achieve the same level of inflation or volume as a healthy lung.

It is therefore essential to monitor pressures carefully and the pressure-volume relationship.

Use of CPAP and BiPAP machines for COVID-19

CPAP and BiPAP machines are typically used in the home to treat sleep apnea (where breathing periodically stops during sleep). They provide basic non-invasive ventilation and for COVID-19, have been approved by Australia's TGA, the US Food and Drug Administration (FDA) and the MHRA in the UK for less seriously ill patients.

These machines need to be slightly modified for use on infected patients, with the addition of a filter to prevent the expulsion of contaminated aerosols. There is a medical opinion that the CPAP mode of ventilation is indeed the best for treating COVID-19, see: https://emcrit.org/pulmcrit/cpap-covid/ (by Josh Farkas, associate professor of Pulmonary and Critical Care Medicine at the University of Vermont). CPAP/BiPAP ventilators are widely used in emergency departments.

Ventilation parameters

The following parameters are among those that should be ideally settable on any ventilator, the first four being a minimum requirement:

- Tidal volume (volume per breath).
- Number of cycles per minute (respiration rate).
- Inhalation/exhalation (I:E) ratio: the ratio of the duration of inspiratory and expiratory phases. 1:2 is a typical setting to mimic natural breathing but can be varied according to several factors.
- Pressure-controlled or volume-controlled modes.
- Trigger sensitivity to stop the patient fighting against the ventilator if they take their own breath; can be flow-triggered or pressure-triggered.
- Rise time of flow in volume-controlled mode, or pressure in pressure-controlled modes.
- Inspired oxygen concentration.
- For PEEP, pressure measurement at the end of the expiratory phase.
- For CPAP, constant airway pressure for inspiration and expiration.
- Peak airway pressure.
- Plateau pressure.
- Expiratory pressure.
- Alarms for any fault conditions.
- Battery backup.

Australian response and regulatory issues

While government departments are often painfully slow to move, the Therapeutic Goods Administration (TGA) in Australia says it will take "a proactive stance with respect to repurposing of alternative devices (such as veterinary devices) and rapid establishment of new manufacturing capability."; see siliconchip.com.au/link/ab14

Via an "expert panel" of ICU clinicians across Australia, the TGA has compiled specifications for the minimum requirements of invasive ventilators for use on COVID-19

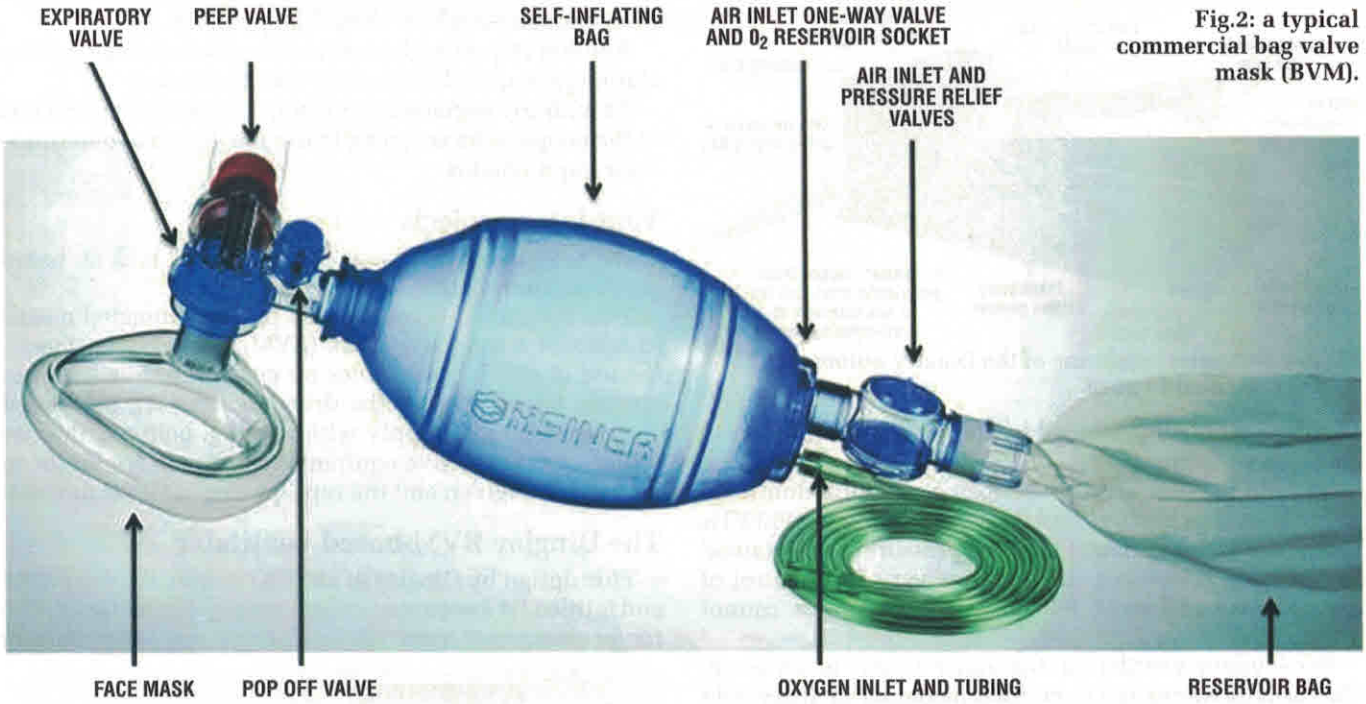


Fig.2: a typical commercial bag valve mask (BVM).

patients and as a guide for manufacturers. See siliconchip.com.au/link/ab15 and siliconchip.com.au/link/ab16 (specifications PDF).

Australian ventilator numbers

Australia is said to have 2300 ventilators in intensive care units and a further surge capacity of 5000 units.

Notwithstanding efforts by the TGA to liberalise regulations for ventilator supply, it has been stated that Australia will have sufficient ventilator numbers to meet demand by more traditional means such as:

a) Using existing equipment such as those currently used in veterinary applications.

b) Purchasing from overseas suppliers

c) Purchasing from existing Australian manufacturers such as Resmed (www.resmed.com.au), with 1000 currently on order.

d) The use of a consortium of domestic manufacturers to produce an existing design (the Medtronic unit comes to mind).

The Australian Government has also approached Ford in Australia about the supply of ventilators, although this would be presumably via the US parent as Ford Australia no longer manufactures here. In the USA, Ford and other car manufacturers such as Fiat Chrysler, General Motors and Tesla have become involved in the production of ventilators and elsewhere, Ferrari, McLaren and Nissan.

Bag Valve Mask (BVM) ventilation

Many open-source ventilator projects use a BVM as the basis of a ventilator system. These devices are typically squeezed by hand in an emergency, either by paramedics in the field or medical staff in hospitals (see Fig.2). Many ventilator projects essentially automate the task of squeezing the bag with a machine, rather than by hand, with various parameters such as rate and volume that can be adjusted.

Possibly the first proposal to use a BVM in a low-cost ventilator design dates to 2010 in the following paper (PDF format): siliconchip.com.au/link/ab17 Also see the video titled *"ApolloBVM Version 1"* at https://youtu.be/u6aDZoBTRwg

Before starting on a ventilator project, it is suggested that you read this document, as it includes a spirometer to measure air volume and is thus able to control it. It also has other useful design features. BVM ventilation has some problems, however.

Important design considerations

It is important to understand that a ventilator is not just a simple air pump; there are many additional requirements. Barotrauma or air-pressure related damage to the lungs is a significant concern. If the air pressure produced by the ventilator is not tightly controlled, it could cause air sacs in the lungs (alveoli) to be damaged or even ruptured.

Seriously ill patients who suffer from acute respiratory distress are very susceptible to barotrauma, because many alveoli are blocked with fluid and air cannot enter, causing the pressure in unblocked alveoli to increase even further. So any ventilator must be able to adjust these parameters. Before designing any ventilator, it is crucial to understand the basic principles.

In general, the type of ventilation provided by a BVM (whether hand-squeezed or automated) is only suitable for less seriously ill patients with good lungs, for short periods. That's because the air delivered is volume-controlled rather than pressure-controlled.

In commercial ventilators, breathing can typically be triggered by the patient. This is for when the patient can still breathe, but they have difficulty and need some assistance. The machine can trigger by several methods, such as detecting a drop in pressure or by airway flow or electrical activity from the patient's diaphragm, which is about to contract.

Detecting these trigger events requires advanced software and a suitably powerful CPU (an Arduino might not be up to it). It is important to avoid the patient fighting against a

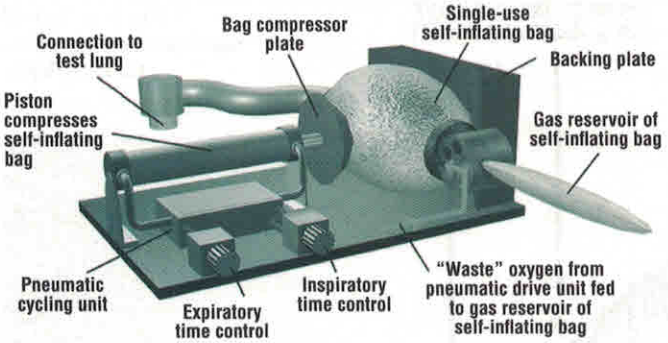

Connection to test lung
Bag compressor plate
Single-use self-inflating bag
Backing plate
Piston compresses self-inflating bag
Gas reservoir of self-inflating bag
Pneumatic cycling unit
Expiratory time control
Inspiratory time control
"Waste" oxygen from pneumatic drive unit fed to gas reservoir of self-inflating bag

Fig.3: a computer rendering of the Dingley automated BVM device described in 2010.

mandatory breath produced by the ventilator, as this can cause barotrauma.

To help prevent alveoli collapsing, a ventilation technique known as Positive End Expiratory Pressure (PEEP) is used, in which a constant positive pressure is maintained in the lungs. However, this requires very fine control of air pressure and most BVM squeezing designs cannot achieve this.

For invasive ventilation, the upper airway is bypassed. This usually warms and humidifies incoming air. If dry, cold air is introduced to the lungs, this can cause damage. So, in this case, the air has to be artificially warmed and humidified.

If oxygen is being added to the air, that also has to be controlled.

Another critical factor is the ability to sterilise components and filters air to stop exhaled virus particles from entering the hospital environment.

It is certainly challenging to come up with a cheap, mass-produced ventilator design. But with enough commitment from enough people, it should be possible.

Another important feature required for ventilators is an alarm system, to alert medical staff to failures.

As with any engineering project, it is essential to first talk to the people who are going to use the device to determine their requirements.

Ventilator projects

We have selected a range of products to look at, based on different designs.

This list includes some based on an automated means to squeeze a bag valve mask (BVM), an oximeter 'hack', the use of an Android device for control, fluidic logic, an electric screwdriver as the drive mechanism, the use of a compressed gas supply with valving, bellows, the use of personal protective equipment such as a respirator to protect a caregiver, and the repurposing of CPAP devices.

The Dingley BVM-based ventilator

This design by Dingley et al. (UK) is from the year 2010 and is titled *"A low oxygen consumption pneumatic ventilator for emergency construction during a respiratory failure*

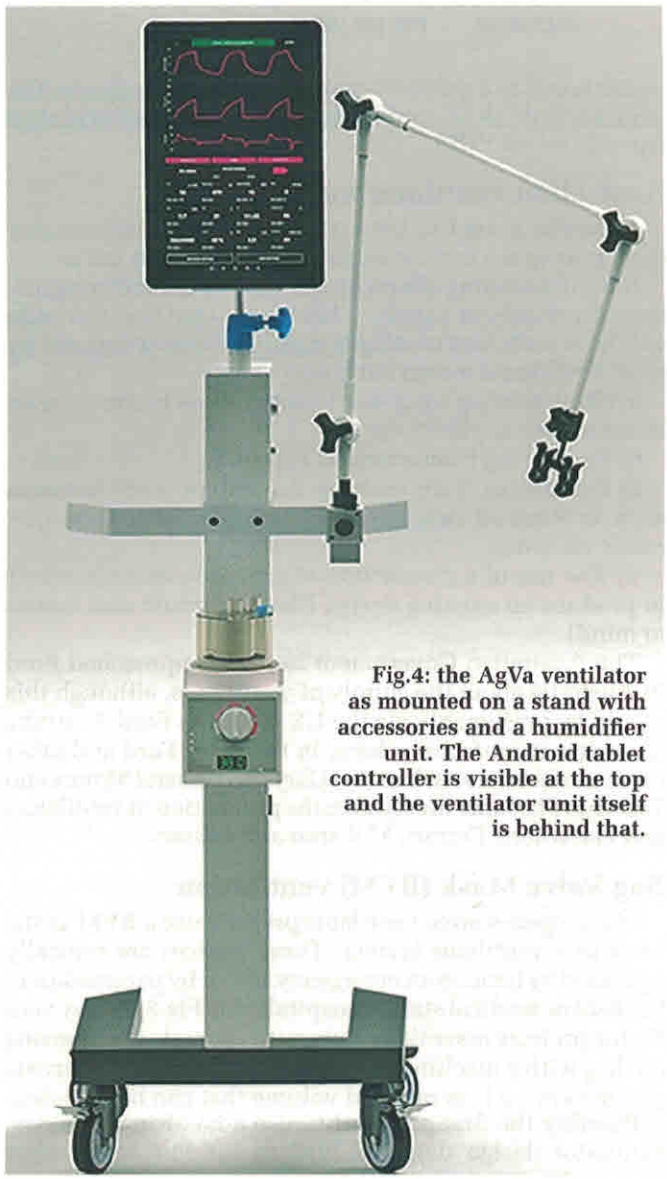


Fig.4: the AgVa ventilator as mounted on a stand with accessories and a humidifier unit. The Android tablet controller is visible at the top and the ventilator unit itself is behind that.

UK MHRA ventilator specifications

For those interested in developing a ventilator, the UK's Medicines and Healthcare products Regulatory Agency (MHRA) has developed a detailed set of specifications for a "Rapidly Manufactured Ventilator System".

The specifications provide recommendations for ventilation functions (at least one ventilation mode and preferably two, with control of oxygen concentration), gas and electricity supply, infection control (must be cleanable), software stability, monitoring and alarm features and ease of use (must require no more than 30 minutes of instruction and pass a usability standard). Parts must be available in the UK supply chain.

The specifications are intended for devices "used in the initial care of patients requiring urgent ventilation".

For ventilators produced under this specification:

"(i)t is proposed these ventilators would be for short-term stabilisation for a few hours, but this may be extended up to 1-day use for a patient in extremis as the bare minimum function. Ideally it would also be able to function as a broader function ventilator which could support a patient through a number of days, when more advanced ventilatory support becomes necessary".

The PDF document is available at **siliconchip.com.au/link/ab1r**

The United States' FDA (Food and Drug Administration) has also relaxed regulatory guidelines for ventilators to assist in their more rapid production, and these are available at **www.fda.gov/media/136318/download**

See the main body text of this article for the Australian TGA guidelines.

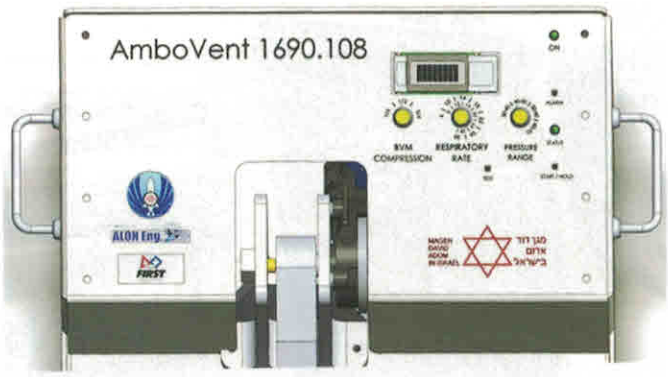


Fig.5: a close-up of the Israeli-developed AmboVent 1690.108 control panel, with the BMV drive mechanism visible at the bottom. It is controlled by an Arduino Nano, and the drive mechanism is powered by a car window lift motor (Dorman model 742-600).

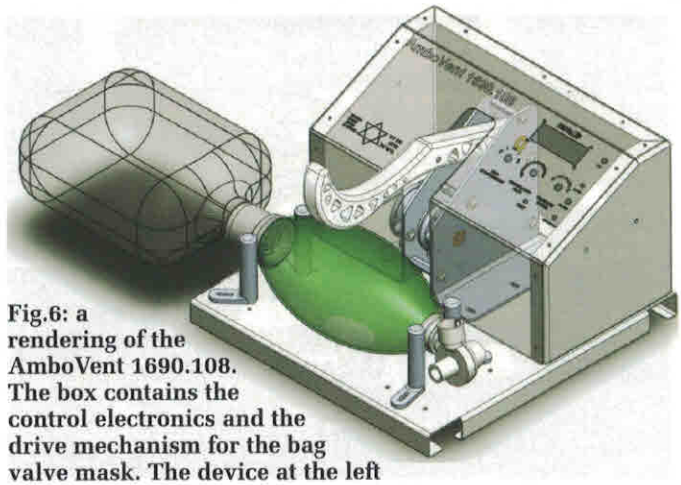


Fig.6: a rendering of the AmboVent 1690.108. The box contains the control electronics and the drive mechanism for the bag valve mask. The device at the left is an oxygen reservoir, to aid in the delivery of extra oxygen when necessary.

pandemic". It seems to be tailor-made for COVID-19. This was a rare case of planning for such a contingency.

The device is described at **siliconchip.com.au/link/ab19** and also see Fig.3.

AgVa tablet-based ventilator

Even before COVID-19, there was a severe shortage of ventilators in countries such as India, which motivated inventors there to design a simple and cheap ventilator using an inexpensive Android tablet for its control electronics and monitoring.

The company has several ventilator models, but is currently producing only their AgVa Advanced model; see **www.agvahealthcare.com** and Fig.4.

Design work by roboticist Diwakar Vaish and neurosurgeon Deepak Agrawal started in 2016. It costs about US$2000 (around AU$3000), which is much cheaper than Western units (around US$10,000/AU$15,000) or more. Production has increased from 500 per month to 10,000 or more, working around the clock.

India's biggest automotive manufacturer Maruti Suzuki is helping to produce these. The device is self-contained and can be set up anywhere with no other infrastructure such as compressed air, and is suitable for long-term use at home for the chronically ill.

The Indian government has banned the export of these units; it is available for purchase now, but only in India.

See the videos titled *"World's cheapest ventilator"* at **https://youtu.be/Y_92mDYfRGs** and *"AgVa Advanced Ventilator Demo Video 2019 March"* at **https://youtu.be/lm79Q3H4Rp8**

AmboVent

The AmboVent was designed by a team of 40 professional engineers, makers, doctors and innovators in Israel and is a bag valve mask-based device.

It was designed for mass production at low cost with off-the-shelf materials (Figs.5 & 6). Its name is derived from the common (commercial) name for a bag mask valve, Ambu bag, and the word "ventilator".

Their website is at **siliconchip.com.au/link/ab1a**

Documentation with the entire blueprints, mechanical and electrical designs, source code and medical/engineering test reports is at **https://github.com/AmboVent/AmboVent**

See these videos for more information:
https://youtu.be/4f6rNCI8iv4
https://youtu.be/xohUDG607s0
https://youtu.be/NeeeegF7KVk (first test on an animal)

Andreas Spiess oximeter 'hack'

During ventilator treatment, it is necessary to monitor blood oxygen levels and heart rate. A simple and inexpensive way to do this is with the use of cheap and readily-available

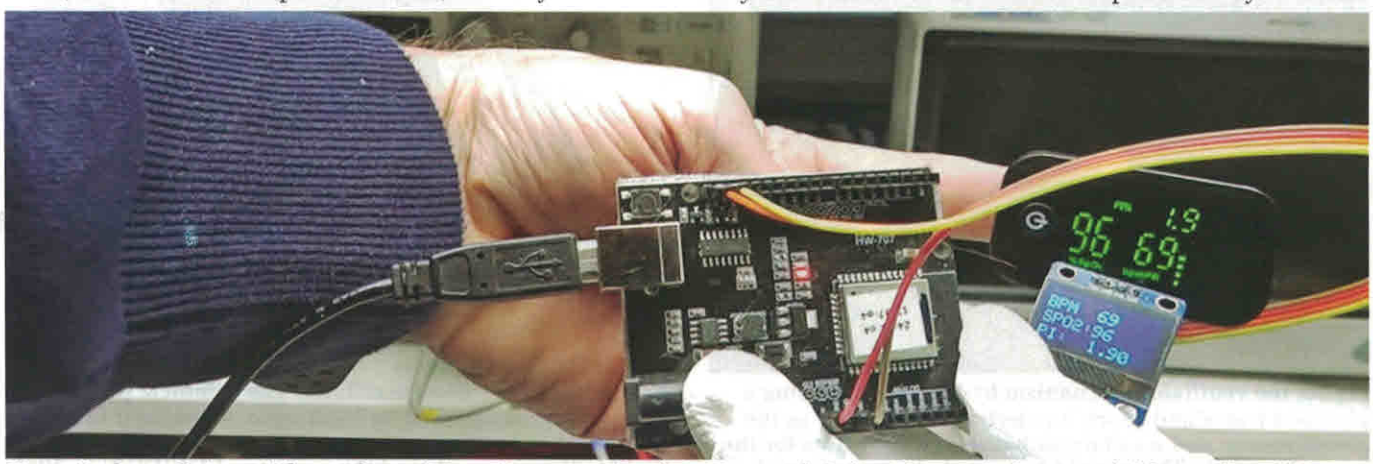


Fig.7: Andreas Spiess with a pulse oximeter (green readout), ESP32 module for Bluetooth data acquisition and an OLED display showing the data acquired by the ESP32.

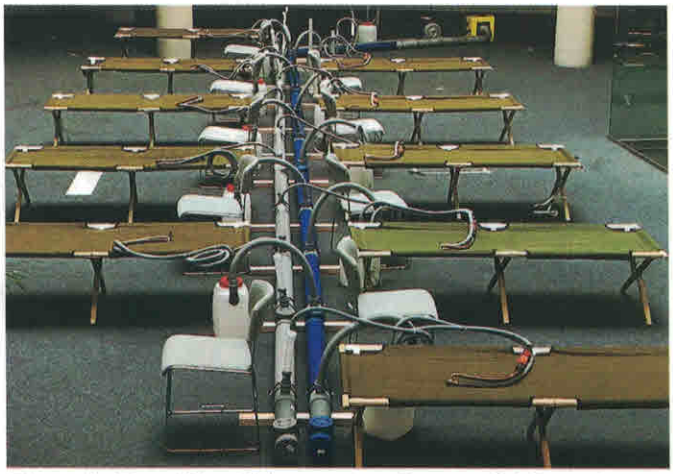


Fig.8: the Breathing Aid concept, where multiple patients connect to a central system.

Fig.9: a computer rendering of the Dyson TTP CoVent attached to the side of a hospital bed.

pulse oximeters. Such devices use light beams of two different wavelengths, passed through thin areas of the body such as fingers or earlobes, to determine the level of oxygenation in the blood and the pulse rate.

We published an article describing in detail how pulse oximeters work in the January 2016 issue; see **siliconchip.com.au/Article/9765**

Some people working on ventilator projects looked at making hardware interfaces to these devices, but since many are equipped with Bluetooth, YouTuber Andreas Spiess decided to decode the Bluetooth signal to extract oxygenation, pulse and perfusion index data.

So it was an entirely software-based project. He used a low-cost Arduino-enabled ESP32 microcontroller with built-in Bluetooth as the listening device (see Fig.7). Also see the video titled *"BLE Oximeter Hack with ESP32 for COVID-19 Projects"* at **https://youtu.be/FIVIPHrAuAI**

A.R.M.E.E. ventilator

The A.R.M.E.E. (Automatic Respiration Management Exclusively for Emergencies; **https://armeevent.com/**) is a fluidic-logic based device, based on a design from the US Army in 1965. It is similar to the Worldwide Ventilator discussed later.

For a detailed description of fluidic logic, see our in-depth article in the August 2019 issue (**siliconchip.com.au/Article/11762**).

Breathing Aid

Breathing Aid (**www.breathing-aid.org/homeen**) is a German project and uniquely, is a centralised system designed to support multiple patients simultaneously. See Fig.8 and the video titled *"Breathing Aid"* at **https://youtu.be/Wee6FnA_eao**

Dyson and TTP

UK vacuum cleaner manufacturer Dyson (**www.dyson.com**), in partnership with technology company TTP (**www.ttp.com**), have designed a ventilator called the CoVent. They received an order for 10,000 units from the UK Government.

It uses a motor and HEPA filters from Dyson's vacuum cleaner designs and is designed to conserve oxygen via rebreathing (see Fig.9). It is also intended to be simple to use.

Electric blower-based portable emergency ventilator

This device is from the University of Utah and was designed in 2013. You can download a PDF file describing it from **siliconchip.com.au/link/ab1b**

Fig.10: the ventilator mechanism by JoergSprave using a plywood frame and gears, an electric screwdriver as the power source and a soft drink bottle as a substitute for the bag valve mask. This should be regarded as a source of ideas, not a working device.

Fig.11: the COVIDIEN Puritan Bennett PB560 ventilator. The complete plans have now been released by Medtronic, allowing it to be replicated or be used as the basis of another model. Note that Medtronic purchased the company COVIDIEN in 2015; the name has nothing to do with COVID-19.

Fig.12: ventilators in production at Medtronic.

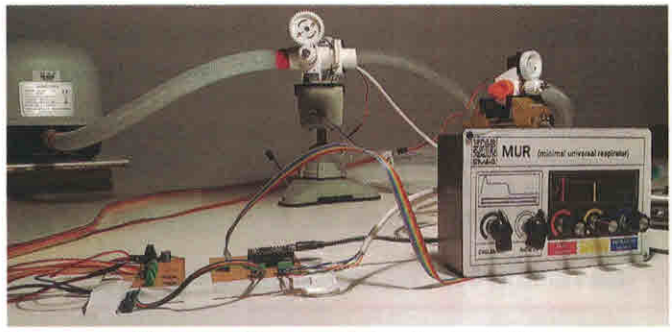


Fig.13: the Minimum Universal Respirator (MUR).

Electric screwdriver-powered ventilator

This is from YouTuber JoergSprave. It uses an electric screwdriver as a power source (see Fig.10). See the video titled *"Saving Lives With a Drill?"* at **https://youtu.be/1ZwsNOvOUoE**

Jeff Ebin's prototype

This is not a published design, but you can see photos of BVM-based prototypes and some useful documentation at **siliconchip.com.au/link/ab1c**

Medtronic

Medtronic (**www.medtronic.com**) is a major international medical products company that includes ventilators among its product portfolio. It has ramped up ventilator production by more than 40% but is also assisting by releasing the plans of one of its ventilator products for free use.

On March 31, Medtronic announced that it was publically sharing all the design specifications for its Puritan Bennett 560 (PB560) ventilator model, which was first introduced in 2010 and sells for US$8,000 (about AU$12000; see Figs.11&12).

The plans include product and service manuals, design requirement documents, manufacturing documents, manufacturing fixtures, PCB drawings, mechanical drawings, 3D CAD files, schematics and software. This enables the exact replication of the entire machine or parts could be used as the basis for another design.

You can register to download the files at **siliconchip.com.au/link/ab1d** or download the first two ZIP file releases from **siliconchip.com.au/link/ab1e** and **siliconchip.com.au/link/ab1f**

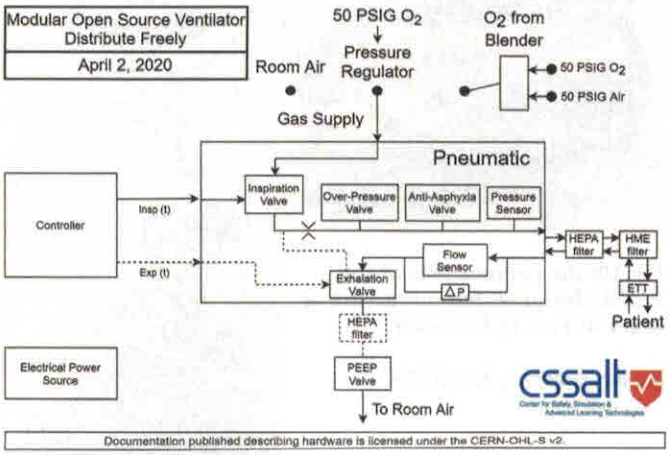


Fig.14: the Open Source Ventilator block diagram.

However, it is best to register at the first link to ensure you get the latest files. The third release contains the source code. There's a lot to explore in those file sets.

One commentator expressed a concern that there might be difficulty getting some parts as this is a ten-year-old design, but we don't know for sure whether that is a problem. If some parts are unavailable, appropriate substitute components would likely be available, or modifications can be made to utilise currently available components.

Medtronic stated that "Our hope is that manufacturers and engineers will use this intellectual property to inspire their own potentially lifesaving innovations.".

MUR (Minimal Universal Respirator)

The MUR (**www.mur-project.org**) is a French project run by four designers with many other contributors. It is designed to be easily reproducible with off-the-shelf components and can run off any air source (see Fig.13). Its documentation is available from **siliconchip.com.au/link/ab1g**

Open Source Ventilator Project

The Open Source Ventilator Project (**siliconchip.com.au/link/ab1h**) is from the University of Florida. It does not use a bag valve mask, but instead uses a compressed air supply to provide airflow. It uses components such as exhalation valves based on bicycle inner tubes, an inspiratory valve based on an Orbit 57280 from a lawn irrigation system and a Bosch BMP280 air pressure sensor (see Figs.14-15).

It is designed to be built quickly, with hardware and electronics store supplies for a parts cost less than US$300 (AU$450). To build one in Australia, you would have to find equivalent plumbing components to the imperial-sized ones.

See the video titled *"Open Source Ventilator Project System Integration Test"* at **https://youtu.be/KhgUCOhOCNM**

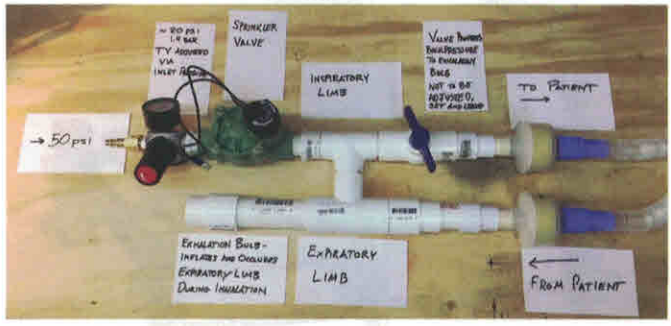


Fig.15: the pneumatic section of the Open Source Ventilator.

Important resources for ventilator designers

Coronavirus Tech Handbook (siliconchip.com.au/link/ab1t) is is a crowd-sourced library with thousands of expert contributions.

Essentials of Mechanical Ventilation, 2nd edition, Dean R. Hess and Robert M. Kacmarek, McGraw Hill, 2002

Principles and Practice of Mechanical Ventilation, 3rd edition, Martin J. Tobin, McGraw Hill, 2013 (siliconchip.com.au/link/ab1u)

The Ventilator Book, William Owens, 2012, First Draught Press

or watch a "live stream" of its endurance testing at https://www.twitch.tv/cssalt

The design files can be downloaded from http://siliconchip.com.au/link/ab1i

PopSolutions OpenVentilator

This Brazilian project (siliconchip.com.au/link/ab1j) recognises a possible shortage of bag mask valves, especially in small villages in Brazil, and therefore uses an alternative system with bellows (see Figs.16 & 17). The documentation is at siliconchip.com.au/link/ab1k and see the video titled *"OpenVentilator (Spartan testing version)"* at https://youtu.be/5DkFc5B6lGQ

Powered Air Purifying Respirator (PAPR)

The PAPR (http://siliconchip.com.au/link/ab1l) is intended for caregivers rather than patients, and allows them to have a contamination-free air supply, so they don't get infected (Fig.18).

See the video titled *"Low-Cost Powered Air-Purifying Respirator (PAPR)"* at https://youtu.be/oS6GA83nbds

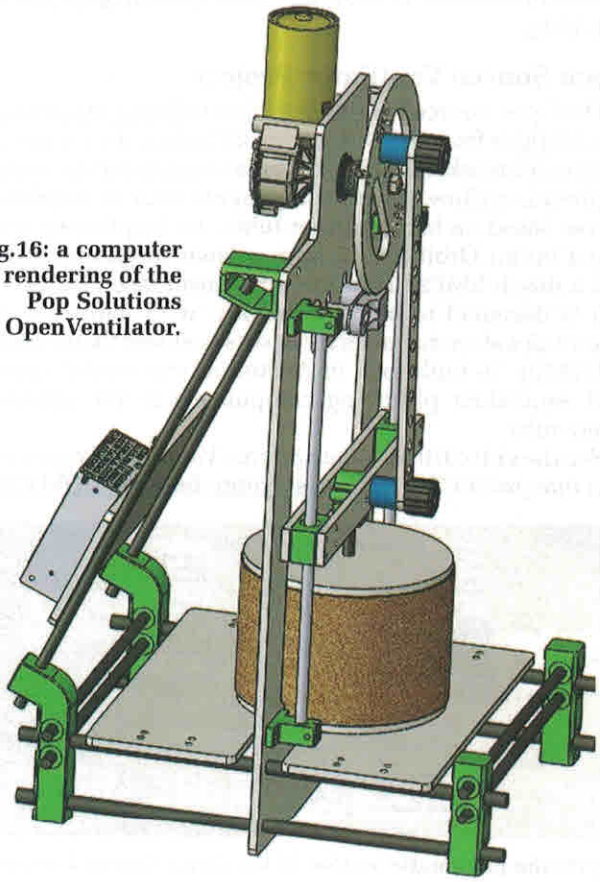


Fig.16: a computer rendering of the Pop Solutions OpenVentilator.

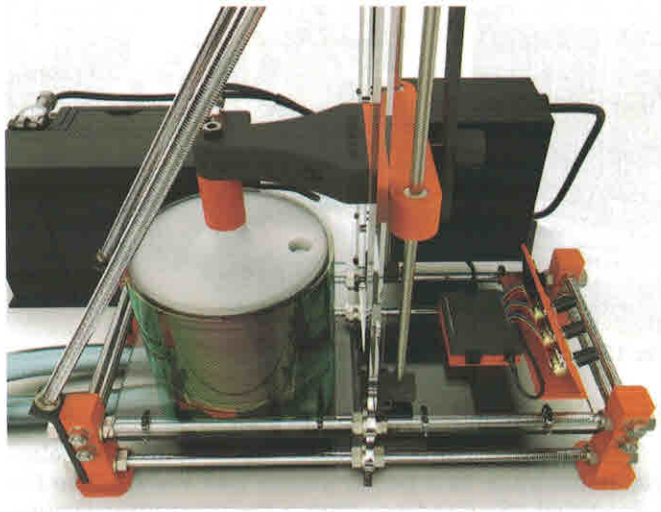


Fig.17: an early prototype of the OpenVentilator.

Rice OEDK Design: ApolloBVM

The ApolloBVM is from Rice University in the USA; see their website at siliconchip.com.au/link/ab1m. It uses a bag valve mask with two Arduinos, one to control the motor and one for the user controls (Fig.19). Later versions will have a third Arduino. It has two redundant motors for safety. Free registration on the site is required to download the construction files.

The device has settings for adult, child and pediatric uses with an adjustable ratio of inspiratory to expiratory time (I:E ratio), variable positive pressure, tidal volume and respiratory rate.

It was inspired by an early student-designed ventilator from 2018-19. The total parts cost is expected to be under US$250 (around AU$375), with a majority of the components being off-the-shelf types. The remainder are 3D printable or laser-cut.

The design team is working with a major manufacturer to mass-produce it, but anyone can manufacture it; you

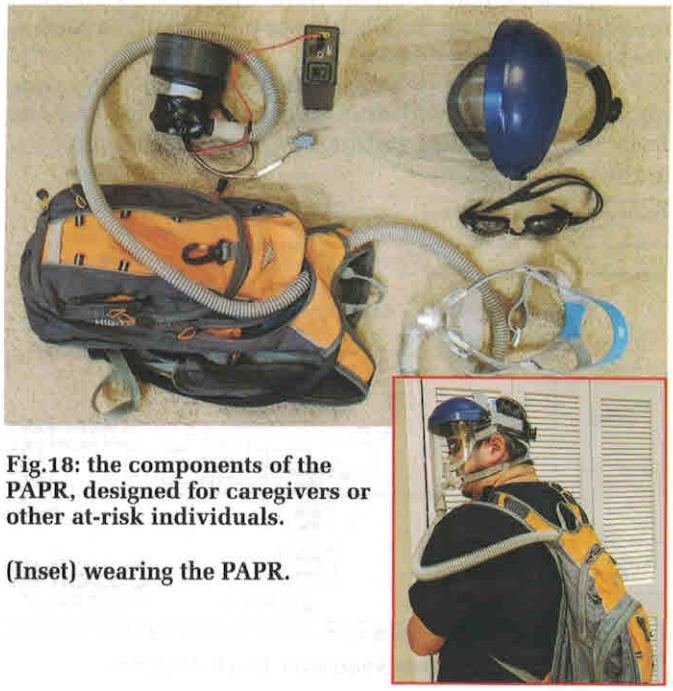


Fig.18: the components of the PAPR, designed for caregivers or other at-risk individuals.

(Inset) wearing the PAPR.

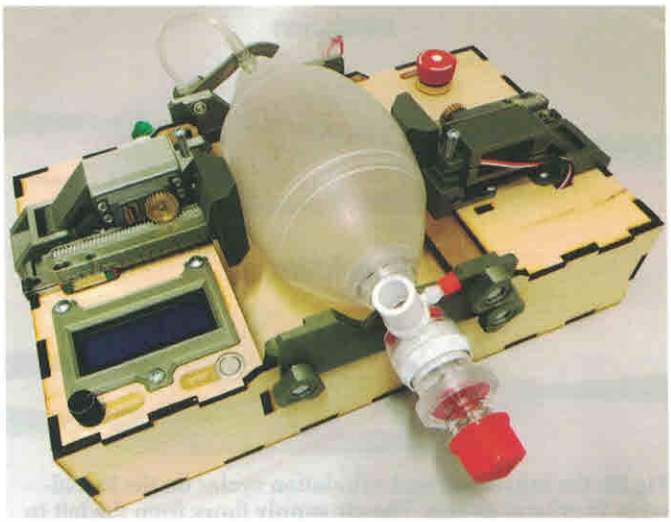


Fig.19: the Rice OEDK ApolloBVM device. Note the bag valve mask in the centre of the unit.

can even make one yourself.

University College London Mercedes HPP

This comes from a collaboration between engineers from University College London, clinicians at University College London Hospital and engineers at Mercedes-AMG High Performance Powertrains (HPP), who build Formula One engines.

They have developed a CPAP device by reverse engineering a device which was out-of-patent and made improvements to it.

The UK National Health Service has already approved it. The device took under 100 hours from the time of the first meeting to production of the first device. As of 29th March 2020, 100 machines are to be produced for clinical trials and production will be rapidly expanded if they are successful.

It is reported from Italy that about 50% of patients are suitable for CPAP treatment rather than the more invasive mechanical ventilation, so that mechanical ventilators can be reserved for the more seriously ill.

A CPAP machine may be all a patient needs to recover if they are still capable of breathing by themselves, but if not, they will have to be transferred to mechanical ventilation.

To better understand the difference between a CPAP machine and mechanical ventilation, read the article at

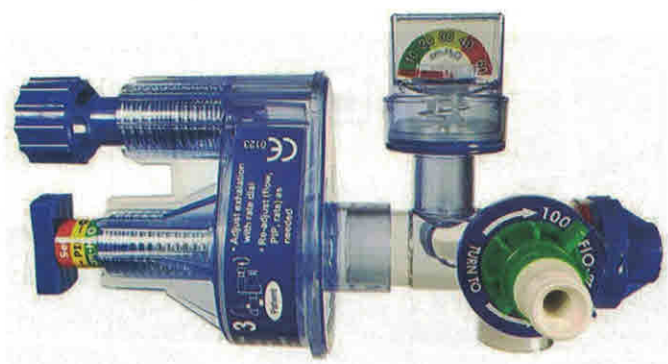


Fig.21: the Vortran model 6123 disposable ventilator device for emergency use. It runs on a supply of compressed air or oxygen with no electronics.

Fig.20: the Open Breath Italy ventilator

siliconchip.com.au/link/ab1o

Also see the video titled *"Mercedes F1 helps upgrade CPAP to fight coronavirus"* at https://youtu.be/Ofpa7-ugY38

Open Breath Italy

The Open Breath Italy ventilator (www.openbreath.it) is another BVM-based device (see Fig.20).

Vortran GO2VENT

The GO2VENT (Gas Operated Ventilator; www.vortran.com/go2vent) is operated by compressed air or oxygen only, with no electronics, and is disposable – see Figs.21 & 22 and the video titled *"VORTRAN GO2VENT Training - Device Overview"* at https://youtu.be/uCMqDvpPzgw

Worldwide Ventilator

The Worldwide Ventilator (www.worldwideventilator.com) uses a fluidic device, specifically a bistable fluidic amplifier. This uses no moving parts to switch between the inhalation and exhalation phases (see Figs.24 & 25).

It works in both assisted and automatic breathing modes,

Fig.22: the GO2VENT attached to a patient.

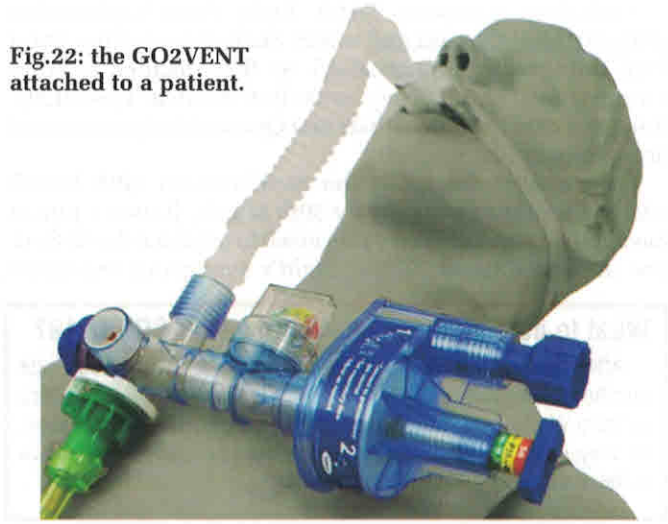
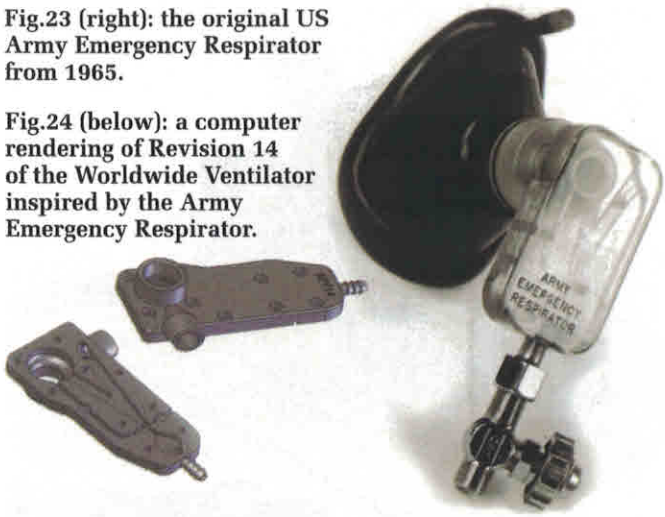


Fig.23 (right): the original US Army Emergency Respirator from 1965.

Fig.24 (below): a computer rendering of Revision 14 of the Worldwide Ventilator inspired by the Army Emergency Respirator.



so if someone can breathe by themselves to some extent, it will assist them.

If they cannot breathe by themselves, it can automatically fill the lungs and then allow them to exhale followed by an inhalation cycle once again. It does this with fluid logic alone and no moving parts or electronics.

Three screws on the device enable the setting of the inhalation and exhalation pressure and the exhalation duration. The device itself requires only an external air supply, plus a face mask or endotracheal tubes, and optionally an oxygen and humidification system.

The inspiration for this device came from the "Army Emergency Respirator" device invented in 1965 at what was then called the Harry Diamond laboratory of the US Army (mentioned above and see Fig.23).

You can see a video of the Worldwide Ventilator titled *"Worldwide Ventilator - April 6th Update"* at **https://youtu.be/St7oJl5TjEg** and you can download the project files from **siliconchip.com.au/link/ab1p**

Project Pitlane

Project Pitlane involves a group of seven Formula 1 racing teams working together to produce ventilators and other medical equipment that's in short supply. See the video at **siliconchip.com.au/link/ab1q** for more information.

Triple Eight Race Engineering

Australian company Triple Eight Race Engineering (**http://tripleeight.com.au/**) was in Melbourne for the Grand Prix, but it was then cancelled. So they decided to build a ventilator (Fig.26). They consulted medical specialists, intensive care unit specialists and Queensland government departments.

They started designing the ventilator on 20th March and had a prototype ready by 30th March. It uses a pincer mechanism around a bag valve mask to produce the airflow. See the video titled *"Triple Eight's emergency ventilator project"* at **https://youtu.be/987rfTSLfJk**

What to do with these ventilators after COVID-19?

After the current COVID-19 crisis, there is likely to be huge numbers of surplus ventilators. As there is a shortage of ventilators in Third World countries, many could be donated to such places. Or they could be kept in storage for the next pandemic, which is inevitable. We just don't know when!

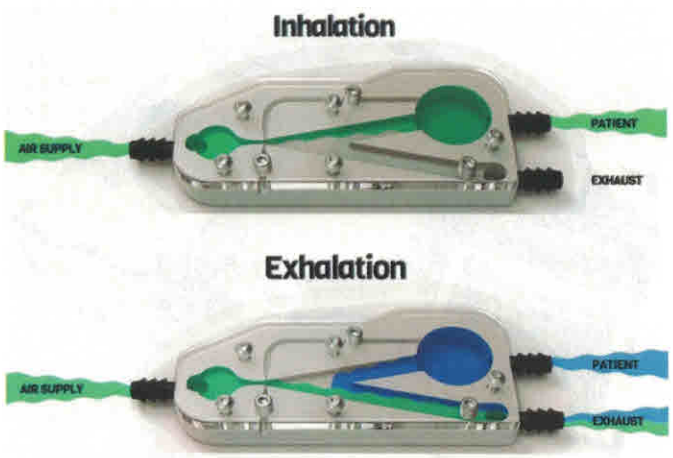


Fig.25: the inhalation and exhalation cycles on the Worldwide Ventilator device. The air supply flows from the left to either the patient or to the exhaust when the patient exhales. It naturally oscillates between the inhalation and exhalation cycles, or it will assist the patient to breathe by helping them inhale or exhale as the patient desires. Switching between the inhalation and exhalation modes is due to the bistable nature of the "gate", at the junction of the main channels.

VentilAid

VentilAid (**www.ventilaid.org**) is an open-source ventilator project from Poland. It uses 3D-printed parts so that it can be produced anywhere that a 3D printer is available. It requires just a few other basic parts, for a total cost of around €50 or AU$90.

The device is under constant development and they are asking for contributors. Visit the website for more details. The latest documentation and printer files are available at **https://gitlab.com/Urbicum/ventilaid**

Also see the video titled *"VentilAid open-source ventilator that can be made anywhere locally"* at **https://youtu.be/t9mFWhHW3sc**

VentSplitter

The VentSplitter (**http://ventsplitter.org/**) is a 3D-printed device designed to allow one ventilator to be used by two or more patients (see Fig.27).

Ideally, their lung capacities and ventilation requirements would be matched, but if they are not, the difference can be compensated for by flow limiters.

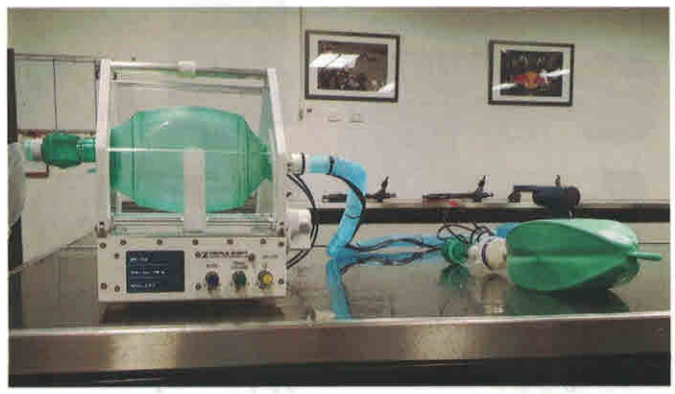


Fig.26: the Triple Eight Race Engineering ventilator.

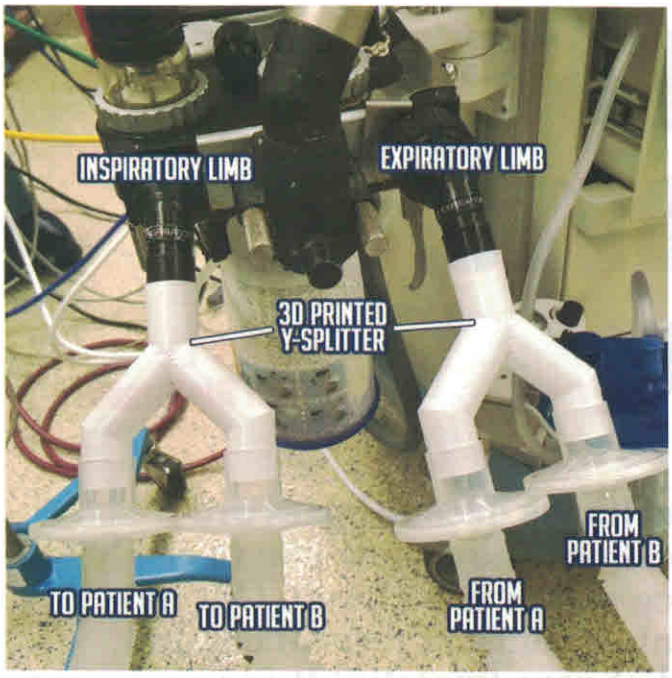


Fig.27: a pair of 3D-printed ventilator splitters.

3D printer files (in STL format) can be downloaded from the website. This type of system has the advantage that an existing commercial ventilator can be used and no mechanical or software development is required. The parts are extremely simple and cheap.

See the video titled *"VentSplitter - 2 Person Ventilation"* at **https://youtu.be/LLS4t0YblrA**

YouTube DIY ventilator

Finally, YouTuber "HowToLou" has an interesting YouTube video entitled *"DIY Ventilator"* at **https://youtu.be/Z7Wbt5_PW-E** (see Fig.28).

It is remarkable for its simplicity and use of readily-available parts although, at the date of writing, it lacks electronics to control speed and other parameters. However, like many of these projects, the basic design is an excellent starting point.

The quality of some or all of the components would have to be improved to meet medical standards. SC

Fig.28: YouTuber HowToLou with his ventilator made with a motor, a bellows pump and a painter's respirator mask.

Other ventilator projects

These are other projects of which we are aware, but had no room to cover. (Google the names for more information!)

DRM127 Ventilator/Respirator
Protofy Team OxyGEN
S-VENT, crowdsourced-ventilator-covid-19
The Open Ventilator, BlueVent3d
OpenVent-Bristol V1.0
Zephyr Open Source Ventilator
MIT 2010 (Husseini et al.)
CaRE-VENT, Saving Babies' Lives Starts With Aquarium Pumps And Ingenuity
RespiraWorks
Gtech Ventilator
MIT E-Vent
VentilatorPAL
Open source ventilator Pakistan
openventilator - KiCad Translation and update of the Medtronic Open-Ventilator
CoronavirusMakers
The Pandemic Ventilator (older)
Cuirass-Ventilator, SparkVent
YACoVV - Yet Another (SARS-)CoV(-2)Ventilator
IMPROV: Inexpensive Maker-Made Piston-Respiratory Open-Source Ventilator
Ad Hoc Ventilator
MIT Low Cost Ventilator, Dr Mujeeb ur Rahman design
Hackaday Rex Ventilator V1
Automatic ambu ventilator
Pandemic Ventilator
Open Ventilator Project
OpenVentilator, Simple device from **www.POMO.cl**
Acute-19, COVID19 Respirador (Vaccarini)
The Breathing Project
Cuirass Ventilator the DIY way
1M Ventilators
MVP, Open Source Ventilator Ireland
Low-Cost-Medical-Ventilator
Pandemic Ventilator Project
Mechanical Ventilator Milano (MVM)
OxVent
Illinois RapidVent
Automatic Resuscitator
Open Source Covid-19 Ventilator Canada
Vortran-Type Pneumatic Ventilator
Low Cost Medical Ventilator
Low-Cost Automated Emergency Ventilator
Low-Cost Ventilator Wins Sloan Health Care Prize
Projecto EAR Celso
Project Open Air
LEITAT1 Respirator,
Respirador RESP19
OperationAIR
CoroVent
Inspiramed
Ventilador Foscal y Unab
Vanderbilt University Commodore Open-Source Ventilator v3.1
PREVAIL NY, DIY-Beatmungsgerät [Respirator]
OpenLung Emergency Medical Ventilator
Inspire OpenLung
COVID-19 Rapid Manufacture Ventilator BVM Ambubag for £80
OpenVent-Bristol, low-cost-medical-ventilator
VentCore
DIY Ventilator Part 1 (YouTube video)
Umbulizer

Touchscreen Wide-range RCL Box

Part 1 – by Tim Blythman

Resistance wheels and resistance/capacitance decade boxes are invaluable tools for prototyping and testing. They allow you to easily try different resistance and capacitance values in a circuit. Our new Touchscreen RCL Box gives you not only a range of resistances and capacitances, but also inductances, all at your fingertip! It can even scan through the range of values automatically.

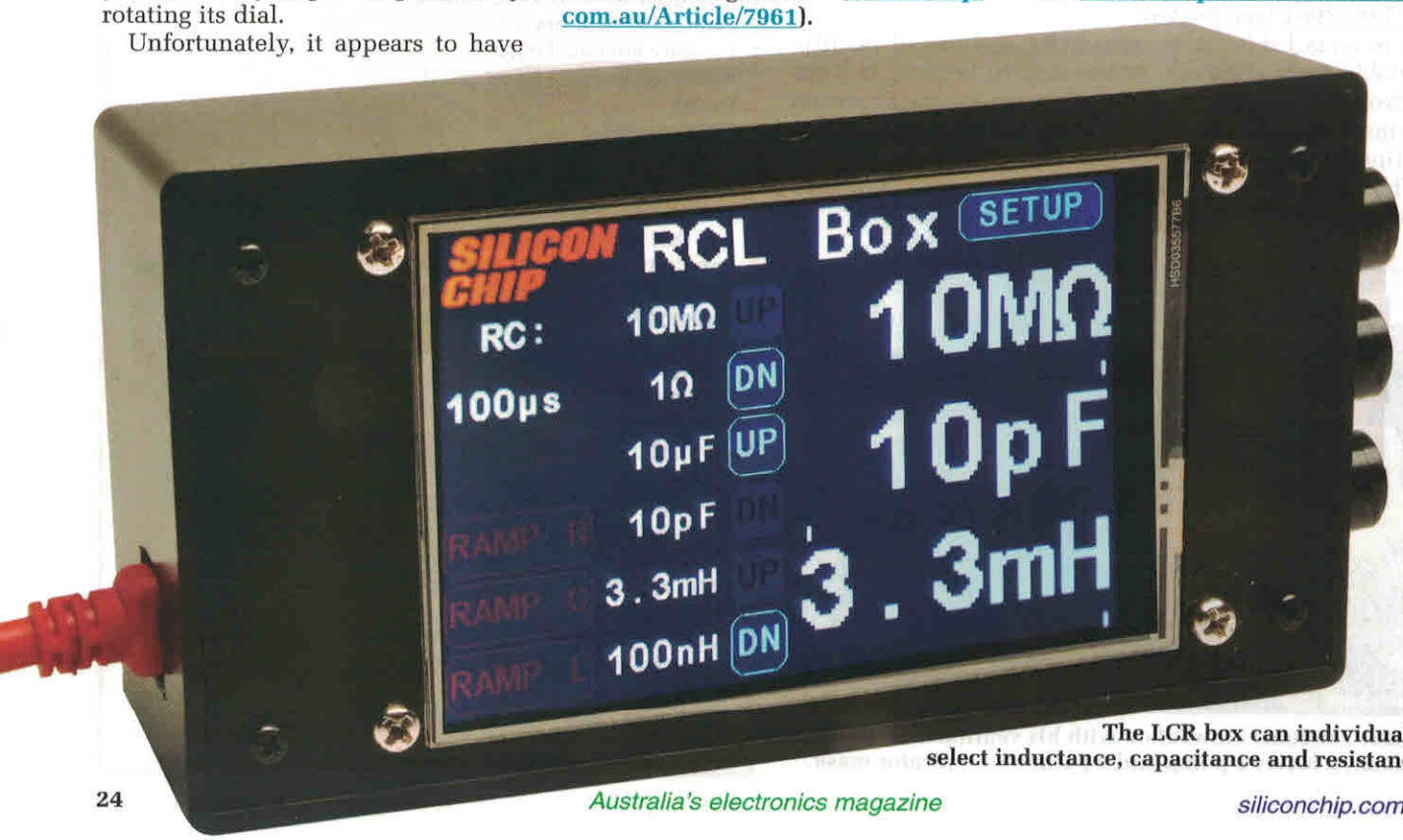
The inspiration for this project was Jaycar's RR0700 Resistance Wheel. It is a compact and handy tool; we have one in our drawer and use it often. It has a good range of resistance values consistent with commonly available parts, and you can easily step through them by rotating its dial.

Unfortunately, it appears to have been discontinued. That is perhaps not surprising when you consider that Dick Smith Electronics were advertising the same product in SILICON CHIP in the late 80s!

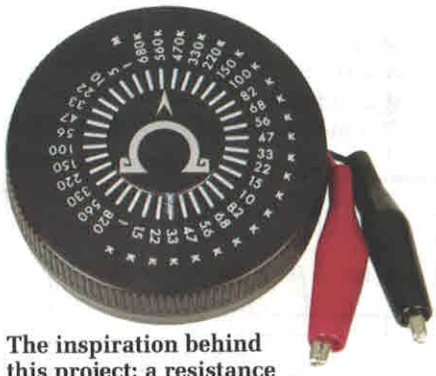
More recently, we published a Resistor-Capacitor Decade Substitution Box in August 2014 (siliconchip.com.au/Article/7961).

This was designed by Altronics, who have it available as a kit **(Cat K7520; siliconchip.com.au/link/ab0z)**.

In 2012, we also published designs for separate capacitor and resistor boxes (siliconchip.com.au/Article/617 and siliconchip.com.au/Article/707



The LCR box can individually select inductance, capacitance and resistance.



The inspiration behind this project: a resistance substitution wheel. We still use one!

Features

- *43 E6 resistance values (1Ω to 10MΩ, ±2%, 1/4W)*
- *19 E3 capacitance values (10pF to 10µF, ±10%, 50V)*
- *10 E2 inductor values (100nH to 3.3mH, ±20%)*
- *Independent control of R, C and L values via a touchscreen interface*
- *Compact design (fits into UB3 Jiffy Box)*
- *Powered from USB 5V*
- *Automatically sweep through value ranges*
- *Frequency display based on RC, LC and RL combinations*
- *Based on Micromite V3 BackPack with 3.5in LCD touchscreen*
- *Programmed in BASIC*

respectively). These each used six knobs to select the desired value.

Those designs provided an extensive range of possible values; however, values which are not part of the standard resistor/capacitor series (E12/E24 for resistors and E6/E12 for capacitors) are of limited use.

Also, they are all fairly large units, fitting into boxes measuring 195 x 145 x 65mm (2014 design) and two 157 x 95 x 53mm boxes (2012 designs).

By contrast, this do-it-all RCL box measures just 130 x 67 x 44mm; considerable smaller than either of the earlier designs, while offering more capabilities and being really easy to drive.

Its only real disadvantage is the need for a power supply, but these days, we all tend to have plenty of USB power sources. You can even use a USB battery bank for portable operation.

Providing various resistances

The Programmable RCL Box is a very different design to any of the previous devices. The addition of a Micromite BackPack with LCD does a lot more than just allow the device to be controlled via its touchscreen interface.

It has separate pairs of banana sockets for resistance, capacitance and inductance. There are 43 resistance values which can be chosen, corresponding to the E6 (six values per decade) values across seven decades, from 1Ω to 10MΩ (see Table 1).

We have chosen the E6 range as it incorporates the most commonly used resistance values. The resistors are switched by small relays, so the resistance terminals are fully isolated from the control circuitry.

Interestingly, we were able to provide these 43 values using only 26 resistors. A set of 14 relays switch these 26 resistors; the relays take up the most space on the PCB.

While we have not done so, it is possible to modify the software to provide even more than the 43 resistance values.

In other words, the 43 E6 values the software currently provides are a subset of those which are possible.

This resistance generation technique gives an accuracy of around ±2% for the final values with the use of 1% resistors.

But most values are much better than this; generally, they are close to ±1%, especially those which correspond to one of the fixed resistor values used.

Any resistance box introduces some parasitic resistance, capacitance and inductance (real resistors have this to some extent too). The PCB layout is designed to minimise these unwanted characteristics where possible.

Capacitances and inductances

Similarly, 19 capacitor values (from the E3 series) from 10pF to 10µF are available, controlled by 10 relays. The inductor range is the smallest, with 11 values, two per decade (from the 'E2' series).

These start at 100nH and go up to 3.3mH, covering the most useful range for most people.

Unlike the resistors, the capacitance and inductance values correspond to

Desired value	Paralleled resistor(s)	Desired value	Paralleled resistor(s)
1Ω	1.5Ω, 3.3Ω, 33Ω	4.7kΩ	15kΩ, 6.8kΩ
1.5Ω	1.5Ω	6.8kΩ	6.8kΩ
2.2Ω	3.3Ω, 6.8Ω, 330Ω, 680Ω	10kΩ	15kΩ, 33kΩ, 330kΩ
3.3Ω	3.3Ω	15kΩ	15kΩ
4.7Ω	6.8Ω, 15Ω	22kΩ	33kΩ, 68kΩ, 3.3MΩ, 6.8MΩ
6.8Ω	6.8Ω	33kΩ	33kΩ
10Ω	15Ω, 33Ω, 330Ω	47kΩ	150kΩ, 68kΩ
15Ω	15Ω	68kΩ	68kΩ
22Ω	33Ω, 68Ω, 3.3kΩ, 6.8kΩ	100kΩ	150kΩ, 330kΩ, 3.3MΩ
33Ω	33Ω	150kΩ	150kΩ
47Ω	150Ω, 68Ω	220kΩ	330kΩ, 680kΩ
68Ω	68Ω	330kΩ	330kΩ
100Ω	150Ω, 330Ω, 3.3kΩ	470kΩ	1.5MΩ, 680kΩ
150Ω	150Ω	680kΩ	680kΩ
220Ω	330Ω, 680Ω	1MΩ	1MΩ
330Ω	330Ω	1.5MΩ	1.5MΩ
470Ω	1.5kΩ, 680Ω	2.2MΩ	3.3MΩ, 6.8MΩ
680Ω	680Ω	3.3MΩ	3.3MΩ
1kΩ	1kΩ	4.7MΩ	4.7MΩ
1.5kΩ	1.5kΩ	6.8MΩ	6.8MΩ
2.2kΩ	2.2kΩ	10MΩ	10MΩ
3.3kΩ	3.3kΩ		

Table 1 – Available resistance values

individual components on the PCB; thus, the tolerance can be expected to be close to that of the parts used.

Again, while we have not done so, extra capacitance and inductance values could be provided if the software were modified.

The complete circuit

The front end display and interface is simply the Micromite LCD BackPack V3 described in our August 2019 issue (siliconchip.com.au/Article/11764).

We have mounted two PCBs behind

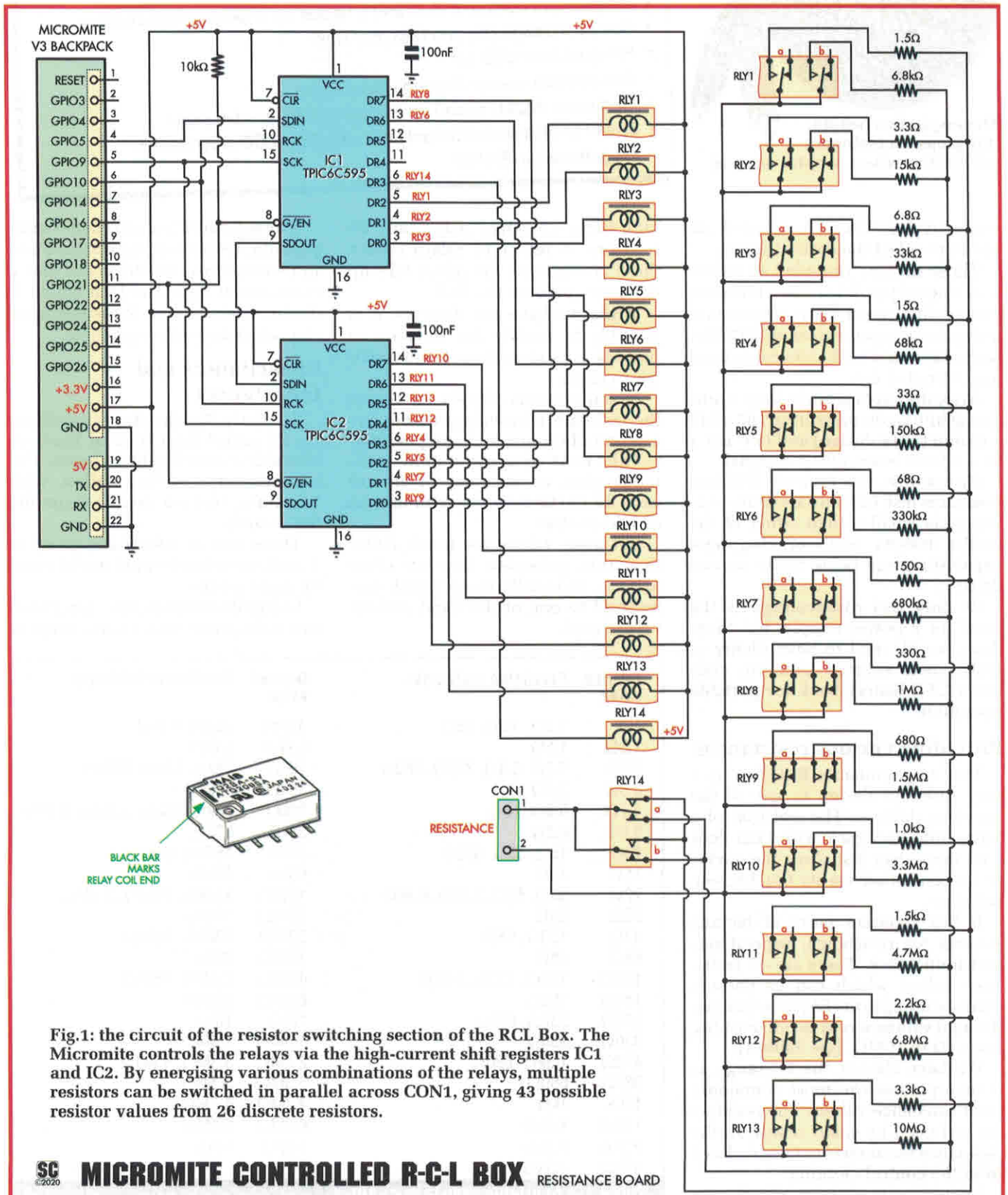


Fig.1: the circuit of the resistor switching section of the RCL Box. The Micromite controls the relays via the high-current shift registers IC1 and IC2. By energising various combinations of the relays, multiple resistors can be switched in parallel across CON1, giving 43 possible resistor values from 26 discrete resistors.

SC ©2020 **MICROMITE CONTROLLED R-C-L BOX** RESISTANCE BOARD

it to provide the RCL Box functions.

The circuit implemented by these boards is shown in Figs.1 & 2. Fig.1 shows the resistor switching functions, while Fig.2 shows the capacitor and inductor switching.

There are effectively two banks of resistors, one switched by the 'a' contacts of RLY1-13 and one switched by the 'b' contacts of RLY1-13. Which bank connects to the external terminals at CON1 is controlled by RLY14. With RLY14 off, the resistors switched by RLY1B-RLY13b are in-circuit, and when RLY14 is on, those connected to

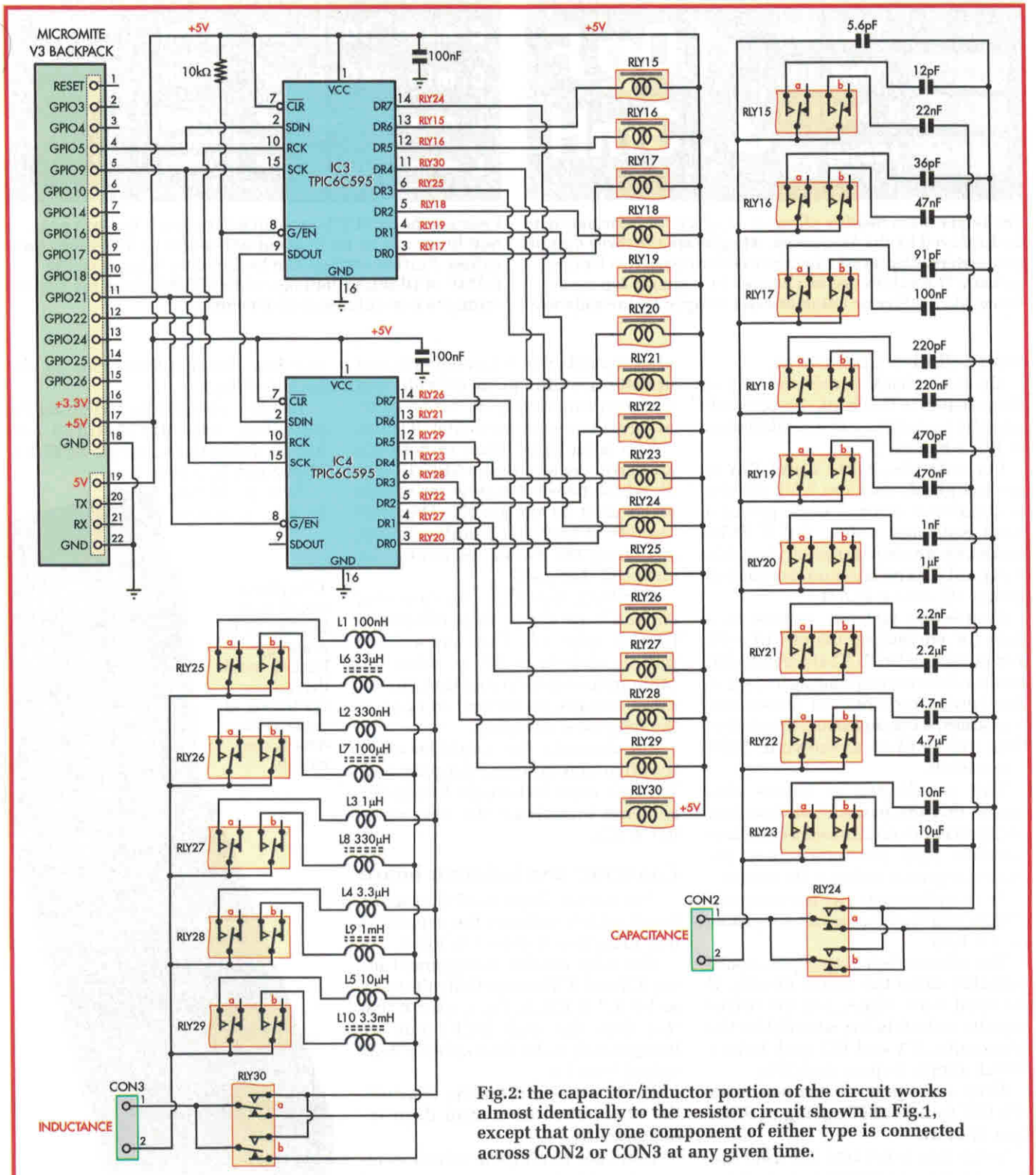
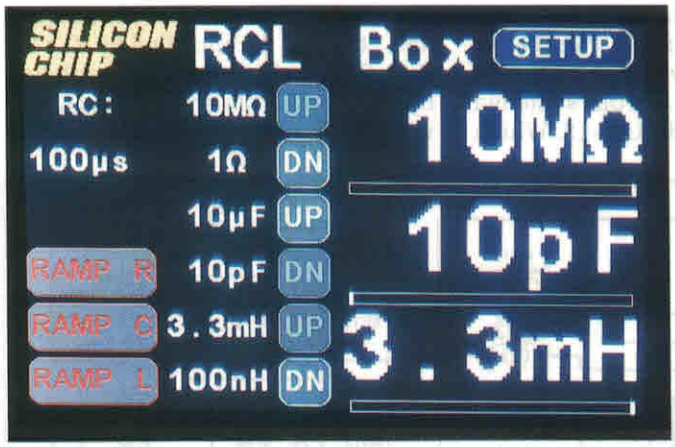
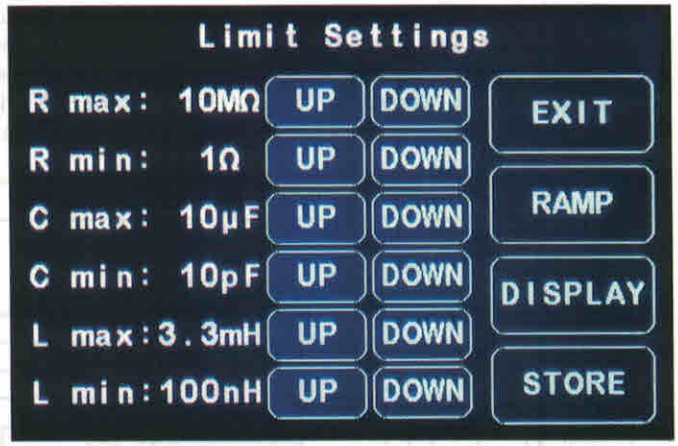


Fig.2: the capacitor/inductor portion of the circuit works almost identically to the resistor circuit shown in Fig.1, except that only one component of either type is connected across CON2 or CON3 at any given time.

MICROMITE CONTROLLED R-C-L BOX CAPACITANCE & INDUCTANCE BOARD



The larger 3.5in display allows a lot of useful information to be displayed by the Micromite. At right are the three output parameters, displayed adjacent to their respective banana sockets. The values can be changed by a simple tap up or down, via a slider or automatically ramped by the software.



Pressing the SETUP button opens the Limit Settings page. Soft limits can be set to avoid non-useful or dangerous test values. Further settings can be found by tapping on the RAMP or DISPLAY buttons, while STORE saves the current setting to non-volatile flash memory.

RLY1A-RLY13a are in-circuit.

Once one 'bank' is selected, any of the resistors in that bank can be paralleled by energising some combination of RLY1-RLY13.

For example, if RLY1 and RLY14 are energised, only the 1.5Ω resistor is connected across CON1, giving a 1.5Ω resistance value. But if RLY2 and RLY4 are also energised, the 1.5Ω, 3.3Ω and 33Ω resistors are paralleled, giving 1Ω across CON1.

Connecting just one resistor at a time (ie, energising one of RLY1-13, and possibly also RLY14) gives 26 different values corresponding to each of the physical resistors. For the remaining values, we energise multiple relays from RLY1-RLY13, as shown in Table 1 (overleaf).

This paralleling of values also means that the parasitic and contact resistances are minimised as much as possible. Also, for some values, the available power rating is increased.

To drive the relays, we are using two TPIC6C595 high-current shift registers (IC1 & IC2).

The Micromite's output pins could probably drive the relays directly if we used 3.3V relays, but the driver circuits make this less stressful for the Micromite. IC1 and IC2 each have a 100nF supply bypass capacitor.

Their serial pins are chained, with SDOUT (pin 9) of IC1 going to SDIN (pin 2) of IC2.

Serial data is fed into IC1 from Micromite outputs GPIO5 (pin 4 of the I/O header) and GPIO9 (pin 5).

These are not the hardware SPI bus pins; the data rate is low enough, and updates are infrequent enough, that this data can simply be 'bit banged'. using general-purpose digital I/O pins.

The latch (RCK) lines of both ICs are driven by Micromite GPIO10 (pin 6), which causes the new serial data to be used to update the DR0-DR7 outputs of both ICs simultaneously, switching the relays (assuming the state has changed).

Similarly, the $\overline{G/EN}$ pins (pin 8) of IC1 & IC2 are driven from Micromite GPIO21 (pin 11). This has a 10kΩ pull-up resistor to 5V, so when the Micromite is not driving this pin, all those outputs are off and so none of the relays are energised.

For example, that might be when the Micromite is being reprogrammed. This pin must be brought low by the software to activate the outputs of IC1 & IC2.

Capacitor and inductor board

The circuit diagram of the second board which switches the capacitors and inductors is shown in Fig.2.

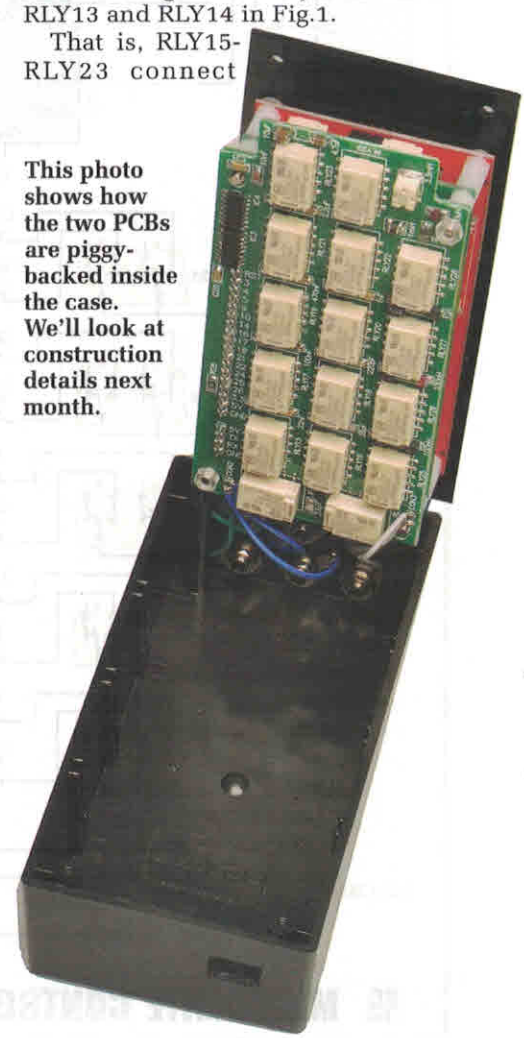
The relay driving arrangement using IC3 and IC4 is essentially the same as for IC1 & IC2 in Fig.1, except that this time, the latch (RCK) pins are brought back to the Micromite GPIO21 output (pin 11).

Thus, with both boards attached, the Micromite can control them independently.

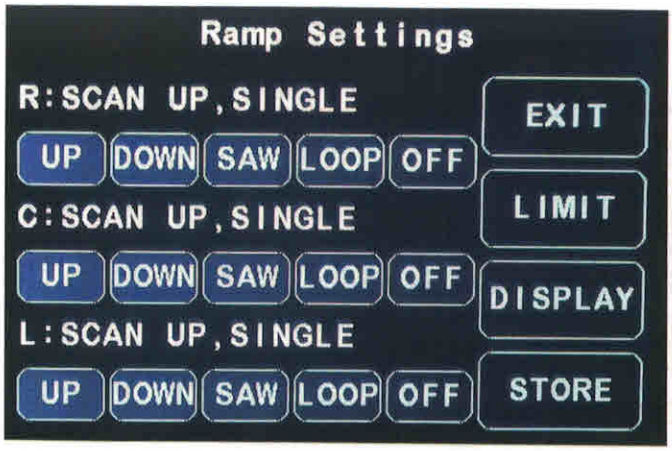
There are 16 relays involved, compared to 14 for the resistors. so all the outputs of both IC3 and IC4 are occupied – by comparison, there are two free driver output pins in the circuit of Fig.1.

10 relays are used for switching the capacitors, with RLY15-RLY23 and RLY24 doing the same job as RLY1-RLY13 and RLY14 in Fig.1.

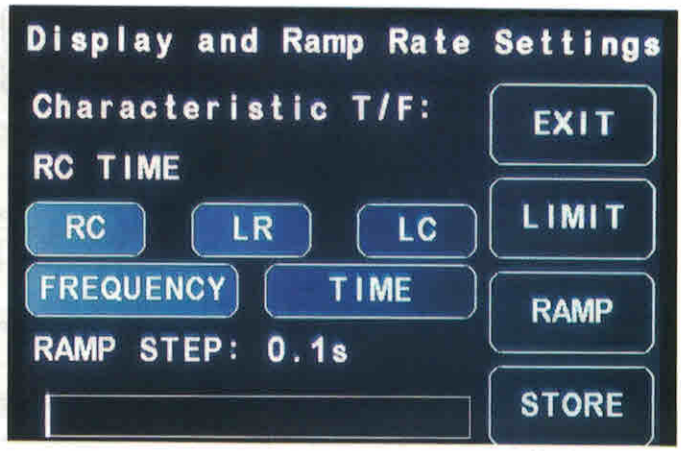
That is, RLY15-RLY23 connect



This photo shows how the two PCBs are piggy-backed inside the case. We'll look at construction details next month.



The Ramp Settings page controls the automatic ramp modes. These can be set to up, down or sawtooth with the option to perform a single or repeated ramp. There are individual settings for resistance, capacitance and inductance; thus, you can ramp resistance up and capacitance down simultaneously if that is what is needed.



The Display Settings page contains the setting for what characteristic time/frequency should be displayed. A choice of either LC, RC or LR combinations can be chosen, with either time constant or frequency being available as further options. The step time for the ramp modes is also chosen by the slider along the bottom of the page.

some number of capacitors in parallel to the NO or NC contacts of RLY24, and RLY24 connects one or the other set to CON2, the "capacitance" banana terminals.

So, just as the circuit of Fig.1 can select or combine resistors to vary the resistance across CON1, the circuit of Fig.2 can select or combine capacitors to control the capacitance across CON2.

Remember, though, that when resistors are paralleled, you get a lower resistance value, but when paralleling capacitors, you get the sum of their capacitances.

To allow the choice of 19 capacitance values by this arrangement, one capacitor (5.6pF) is permanently connected to one leg.

While this appears to remove the option of having no capacitance across CON2, in practice there is about 4.4pF of parasitic capacitance already present, so this rounds it up to a neat 10pF.

In fact, if you can measure the parasitic capacitance, you can tweak the values of the 10-100pF capacitors, increasing the accuracy of the 'C' part of the RCL box.

We'll discuss that possibility in detail later, in the component selection section.

As with the resistors, the software doesn't provide for all the possible capacitance options. Instead, we limit the choice to the E3 range to keep things simple.

If we could have combined capacitors to provide the E6 range, we would have, but you get oddball values instead. So in fact, only one capacitor is selected in time, except for the 5.6pF capacitor of course.

Inductors

The inductors are switched by RLY25-RLY30, with RLY30 switching between two banks of five inductors. The pairs of inductors are toggled in or out of circuit by RLY25-RLY29.

As for the capacitors, each inductor corresponds to one output value, with a range of intervening values being theoretically possible if more than one inductor is switched in. They would be switched in parallel too. The selected inductance is then made available at CON3.

Note that with this design, the resistance, capacitance and inductance are all independent, short of parasitic coupling between the components.

This small amount of coupling is an inevitable result of combining these functions in the same device.

PCB design

Initially, we tried to design a single PCB to provide all of these functions, but we found it to be quite difficult to cram it all into a reasonably-sized board.

We considered using a four-layer PCB but ultimately decided not to do so, as this would rule out home etching entirely. That might also have led to a relatively expensive commercially-manufactured board.

But the design lends itself very well to being split into two double-sided PCBs, so that is what we did. One PCB houses the components that provide the resistor functions, while a second one has the capacitors and inductors fitted.

In other words, these PCBs correspond precisely to the circuits of Fig.1 and Fig.2. These boards are depicted in the PCB overlay diagrams, Figs.3 and 4.

In essence, the two PCBs are mounted back to back, forming a sort-of-four-layer PCB.

It is possible to build just a resistor box, or just a capacitor/inductor box, by building one PCB or the other. But we will describe the construction as we expect most readers will, incorporating all of the features.

We have used mostly surface-mount components as they save some board space, since they only occupy space on one side of the board. All the resistors, capacitors and inductors are 1206-size (3216 metric or 3.2 x 1.6mm) or larger, so they are not difficult to work with.

Unsurprisingly, the remaining space on both PCB is mostly taken up by the 30 relays.

Software features

The software required to provide equivalent features to a passive resistor or capacitor box is fairly simple.

The Micromite just needs to be programmed to produce serial data for the shift registers corresponding to the combination of relays for the desired value(s).

What is more interesting are the

extra features that we have added now that we have some processing power available.

The first feature we added to the software is the ability to limit the outputs to specific values.

This is handy since you can 'lock out' certain component values if they would either be too low/too high for the circuit you are testing, and would either cause damage or prevent it from functioning.

Even more useful (we think!) is that we have set it up so that the value the RCL Box is producing can change automatically.

Troubleshooting and prototyping is typically a time when both your hands are busy holding multimeter leads or wires in place; you won't have a free hand to adjust the output on the RCL Box at the same time (unless you have three or more hands!).

So our Box has a mode where it can automatically sweep each value up and down, allowing a range of values to be quickly and easily tested.

Also handy if you are dealing with AC or oscillator circuits is a feature which calculates and displays the resonant frequency of the currently selected RC, LC or LR combination.

This may not always align with the circuit frequency, but can be a handy guide.

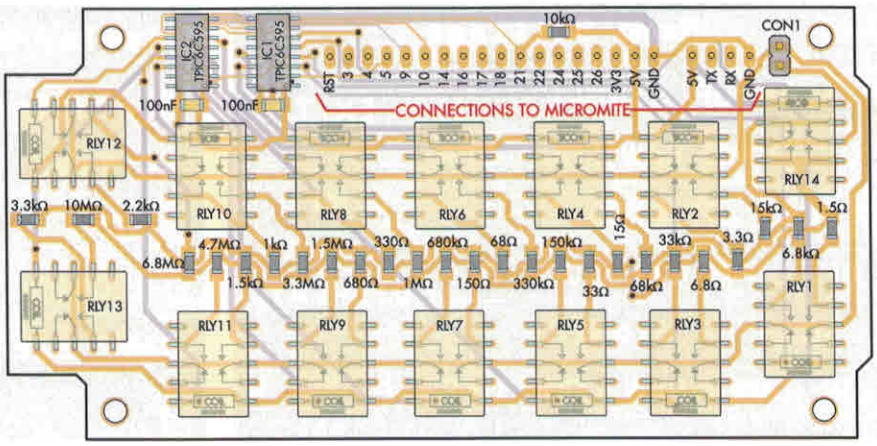


Fig.3: all the components shown in Fig.1 are located on this PCB, which plugs directly into the Micromite LCD BackPack board via a pin header soldered along the top. The resistor banana terminals connect to pin header CON1 (or directly to its PCB pads) via flying leads. On each of the relays, a bar at one end indicates their orientation on the PCB

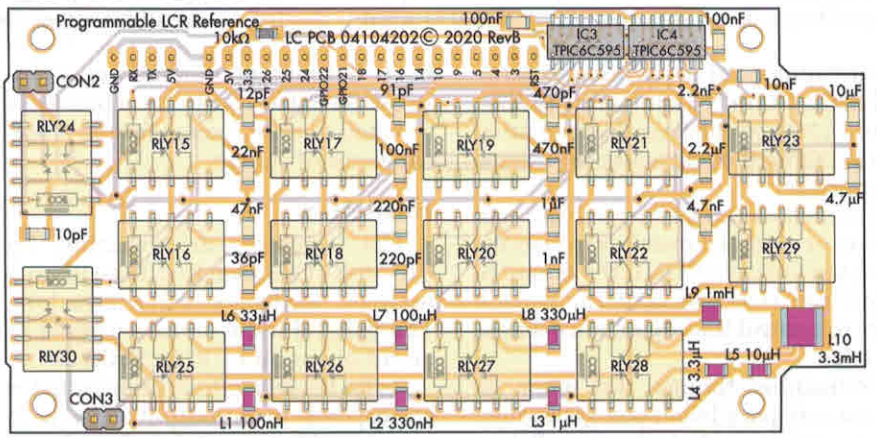


Fig.4: this capacitor/inductor PCB is arranged similarly to the resistor PCB, and they can be soldered back-to-back, sharing the one set of pins along the top. This allows them both to be plugged into a header socket on the back of the Micromite BackPack, making a neat module that fits into a small UB3 jiffy box.

Component selection

While we had no trouble sourcing the necessary parts, it's worth noting that the build requires a large number of parts with different values, one of each, and some of these parts cost practically as much for one or ten as they are so small.

The exact components you purchase is more critical for the capacitors and inductors.

The actual resistance, capacitance and inductance values you will get at the RCL Box's terminals depends not just on the components fitted, but also the resistance, capacitance and inductance of the PCB traces and relay contacts.

The relays we have chosen add about 75mΩ of resistance, so even with two in the circuit, that isn't a big deal. The PCB tracks add up to at least 68mΩ or more, as some PCB tracks are longer.

While you could compensate for this, it is still negligible for most values. Indeed, the contact and lead resistance of your connections between the RCL Box and your test circuit could easily be more than this.

Capacitor selection

The parasitic capacitance across open relay contacts is around 4pF across all the capacitor relays (since most relays will have open contacts at any one time).

Our measurements indicate that this is the biggest contributor to stray capacitance, although it will be subject to lead and contact variations too; even moving the leads can change the measured capacitance noticeably!

As mentioned earlier, the baseline capacitance is set to 10pF by the 5.6pF capacitor near RLY24, in parallel with the stray capacitance. This is always in circuit, and is the reason why the next values are 12pF, 36pF and 91pF; they add to the 10pF to produce the (nominal) 22pF, 47pF and 100pF values.

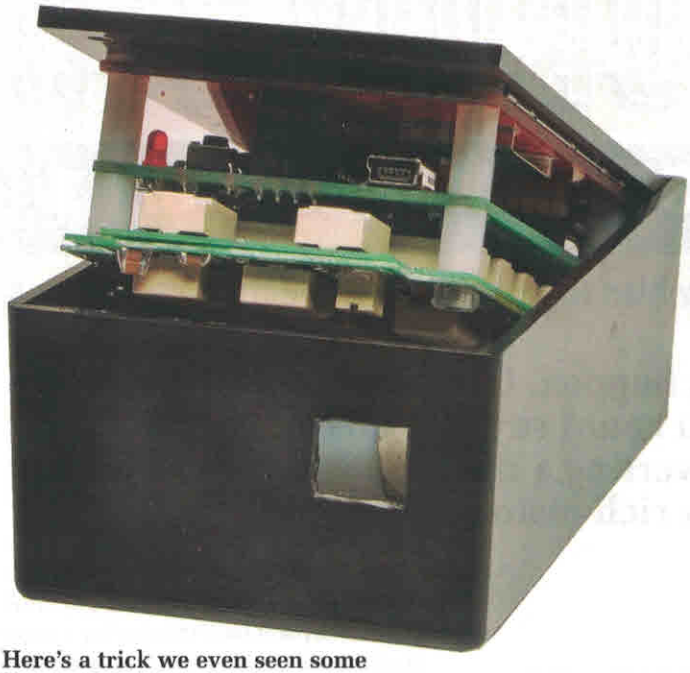
If you have an accurate picofarad meter, leave the 5.6pF part off and measure the output capacitance once the build is complete. You can then subtract this from 10pF and choose the closest capacitor value you can get.

We've specified 100V X7R MLCC capacitors throughout. If you have trouble getting these, and are not concerned about operation at higher voltages, then a slightly lower voltage rating (say, 50V) could be used instead.

The PCB footprints we have used are slightly oversized (to allow more room for hand soldering) and will accommodate slightly larger parts if necessary.

You might even be able to use a small leaded part in one or two places, if required.

We also tried a trick which the part



Here's a trick we even seen some manufacturers perform; stacking multiple capacitors to achieve a higher capacitance value. In this case, we have combined a pair of 4.7µF parts to replace a single 10µF part. It's not hard to do as long as you don't apply too much heat.

manufacturers sometimes pull off too. Instead of ordering a 10µF capacitor part, we stacked a pair of 4.7µF capacitors.

If you have to buy your parts in sets of 10, this will save you some money, although the nominal value will be slightly off.

We soldered the two capacitors together, then fitted them as though they were a single part. This works fine unless you apply too much heat and the two parts fall apart. In the past, we've also had success in soldering one SMD component to the board, then soldering another one on top. The accompanying photo shows how the result looks.

Inductors

You will have to pick and choose some inductors that match our specifications. There's a wide range of nominal frequencies, maximum currents and resistances to choose from, apart from actually having the correct inductance value.

You may have to compromise on some specifications to get parts that will fit. We suspect that this variation is why there aren't as many inductor boxes around.

As for the capacitors, the PCB footprints suit parts larger than 3216/1206 size. Many inductors come in in 3226/1210 size (more square than 3216/1206 at 3.2 x 2.6mm); that is what we used for most of our parts.

You can also stack inductors to get different values, but remember that their value is reduced when connected in parallel, just like resistors (the current rating increases, though).

But beware that two inductors in close proximity could interact, giving a different value to that expected.

Construction

Next month, we'll have the full construction and usage details for the RCL Box. SC

Parts list – RCL Box

1 Micromite BackPack V3 module with 3.5in LCD touchscreen [eg, built from an SC5082 kit]
1 Resistor module (see below)
1 Inductance/Capacitance module (see below)
1 UB3 Jiffy Box
6 banana sockets (CON1, CON2, CON3)
30cm of medium-duty hookup wire
4 M3 x 9mm tapped or untapped insulating spacers (eg, Nylon)
4 M3 x 32mm panhead machine screws
4 M3 hex nuts (Nylon or steel)
1 18-way female header
1 4-way female header
1 18-way male header strip
1 4-way male header strip
Kapton (polyimide) or other insulating tape

Resistor module

1 double-sided PCB coded 04104201, 115x58mm
14 SMD low-profile miniature signal relays with 5V coil (eg, Panasonic TQ2SA-5V)
2 TPIC6C595 high-current shift register ICs, SOIC-16
2 100nF 50V X7R 3216/1206 size ceramic capacitors

Resistors (all 1 of each, SMD 1% 3216/1206 size; SMD markings shown)

10MΩ	106 or 1005	6.8MΩ	685 or 6804
4.7MΩ	475 or 4704	3.3MΩ	335 or 3304
1.5MΩ	155 or 1504	1MΩ	105 or 1004
680kΩ	684 or 6803	330kΩ	334 or 3303
150kΩ	154 or 1503	68kΩ	683 or 6802
33kΩ	333 or 3302	15kΩ	153 or 1502
10kΩ	103 or 1002	6.8kΩ	682 or 6801
3.3kΩ	332 or 3301	2.2kΩ	222 or 2201
1.5kΩ	152 or 1501	1kΩ	102 or 1001
680Ω	681 or 680R	330Ω	331 or 330R
150Ω	151 or 150R	68Ω	680 or 68R0
33Ω	330 or 33R0	15Ω	150 or 15R0
6.8Ω	6R8 or 6R80	3.3Ω	3R3 or 3R30
1.5Ω	1R5 or 1R50		

Inductance/Capacitance module

1 double-sided PCB coded 04104202, 115x58mm
16 SMD low-profile miniature signal relays with 5V coil (eg, Panasonic TQ2SA-5V)
2 TPIC6C595 high-current shift register ICs, SOIC-16
1 10kΩ 1% 3216/1206 size chip resistor (code 103 or 1002)

Capacitors (all 1 of each, SMD 3216/1206 size X7R 100V if possible; see text)

10µF	100nF (3 required)	1nF
4.7µF	47nF	470pF
2.2µF	22nF	220pF
1µF	10nF	91pF
470nF	4.7nF	36pF
220nF	2.2nF	12pF

5.6pF (or vary based on stray capacitance; see text)

Inductors (all SMD 3226/1210 or 3216/1206 size except where noted)

3.3mH (5mm x 5mm footprint)

1mH	330µH	100µH	33µH	10µH
3.3µH	1µH	330nH	100nH	

VINTAGE WORKBENCH

The Tektronix Type 130 LC Meter – Part 1

How it works

By Alan Hampel, B. Eng. (Electronics, Honours)

Unfortunately this sort of thing does happen. I was ripped off by a dodgy eBay seller – sold a bill of goods, you could say. But this story has a happy ending. I had a lot of fun converting a dirty, unusable relic into an as-new laboratory instrument with a rich history.

The T-130 LC meter from Tektronix was built from 1954 until 1975 and has five capacitance measuring ranges (3pF, 10pF, 30pF, 100pF and 300pF) with 1% FSD accuracy and a stable zero. Thanks to its 4.5-inch (~11.5cm) meter, it can easily resolve down to 0.05pF. It also has five inductance ranges from 3µH through to 300µH.

I bought it because I needed a capacitance meter that could accurately resolve sub-picofarad values for a project. I also collect and restore valve test gear, so the T-130 seemed like an ideal candidate. As such, one for sale on eBay caught my eye. The price was very reasonable, and it looked clean and original in the photos, so I bought it.

The seller claimed he had run it for a couple of days with a 25pF capacitor, and got a correct stable reading.

When it arrived, the package was not damaged, but turning it over produced clunking sounds. That's a bad sign!

As it turned out, the instrument was generously coated inside and out with cigarette smoke residue, and was inoperative due to many faults.

The origin of the T-130

During Tektronix's early days (see the side panel for a brief history), they needed an instrument to measure small capacitances, eg, stray wiring capacitance and valve capacitances, as well as small inductances. The production lines needed a stable instrument, usable by semi-technical operators. The lab needed accuracy and sub-picofarad sensitivity.

After joining Tek in 1951, young engineer Cliff Moulton designed the T-130 to meet just these needs.

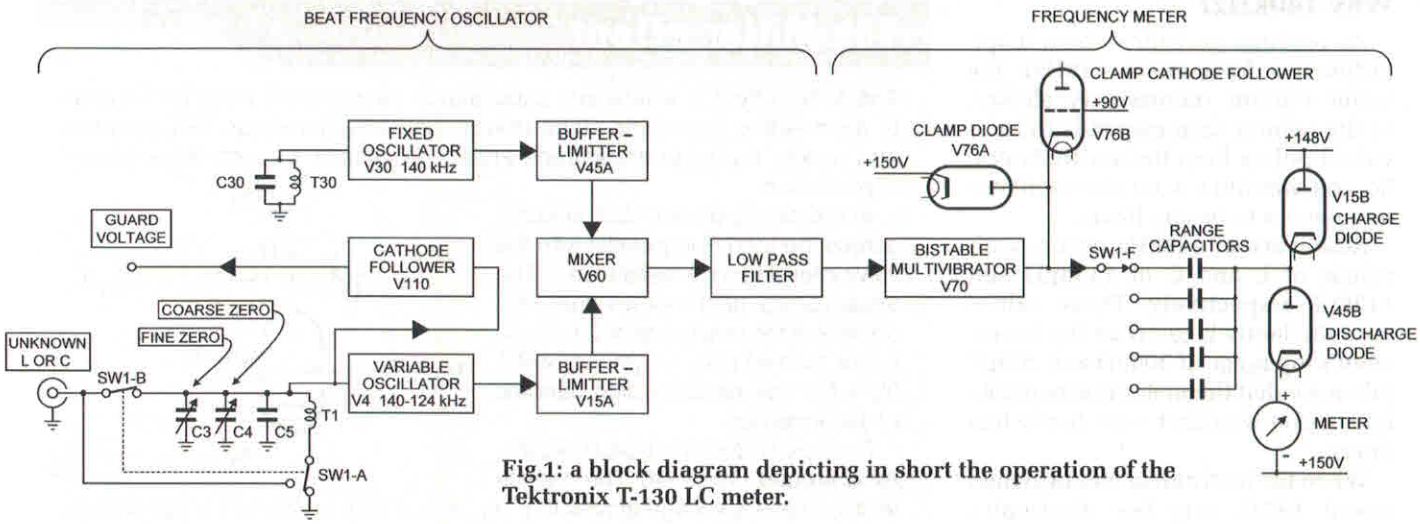


Fig.1: a block diagram depicting in short the operation of the Tektronix T-130 LC meter.

The T-130 was not intended for sale to Tek's customers – it was purely for use in the factory. It therefore wasn't designed and engineered to quite the same standards as Tek's catalog products. It was quite cramped inside, with components hidden under other parts, compromising ease of repair. But it used innovative circuitry, offered excellent performance and was easy to use.

Factory visitors noticed it in use, and many asked if they could buy one. So it was cleaned up and documented, with production beginning in 1954. It remained in the catalog until 1975, indicating just how good an instrument it was.

How it works

It operates on the beat-frequency oscillator principle. Refer to the block diagram, Fig.1; a built-in analog frequency meter responds to the difference in the frequency of two oscillators. The capacitance (or inductance) under test forms part of the tuned circuit of one of the oscillators, thus shifting its frequency.

The fixed oscillator runs at 140kHz, set by tuned circuit C30/T30.

With RANGE SELECTOR switch SW1 in any of the "µµF" (picofarad) positions, the variable oscillator is tuned by T1 and the capacitance connected to the UNKNOWN jack plus capacitors C2-C5. With SW1 in any of the "µH" positions, the tuned circuit comprises C3-C5 and T1 in series with any inductance connected to the UNKNOWN jack.

C3 and C4 are adjusted to get 140kHz from the variable oscillator with whatever wiring or cabling capacitance or inductance appears on the UNKNOWN jack. When the capacitor or inductor under test is connected, the variable oscillator frequency drops below 140kHz in approximate proportion to its value.

An LC oscillator's frequency is proportional to the square root of total tuning capacitance and to the square root of total inductance; but in this case, the change is kept approximately linear by keeping the highest calibrated inductance or capacitance under test to a small fraction of the total. The meter scales are calibrated to match.

After passing through buffers (operating in an overdriven, limiting mode) to prevent the oscillators from coupling together and synchronising, the two frequencies are mixed, and a low pass filter substantially removes all but the difference frequency. The difference frequency is approximately 62Hz per UNKNOWN pF or µH, and is fed to a bistable circuit (Schmitt trigger) to make the waveform rectangular.

Each time the multivibrator output jumps to its low level, the 'clamp cathode follower' turns on and holds the output very close to +90V (set by 100kΩ resistor R78), as the impedance of a cathode follower is 1/gm – in this case, 160Ω. The selected range capacitor is charged to +150V less the 90V via the charge diode. The amount of charge is always the same.

Each time the multivibrator output jumps to its high level, the cathode follower is cut off, and the clamp diode limits the voltage to very close to +150V. The range capacitor is discharged via the discharge diode into the meter. The meter thus receives a pulsating direct current with an average magnitude accurately proportional to frequency.

The history of Tektronix

Tektronix was founded in December 1945 by four friends: Howard Vollum, a young engineer/physicist; Jack Murdoch, radio technician; Glen McDowell, accountant; and Miles Tippery, who served with Murdoch and McDowell in the US Coast Guard during World War II. Vollum was the president and chief engineer.

Tektronix, or "Tek" as it became known, started at the beginning of the post-war golden age of the American electronics industry. Their innovative and high-class products led to rapid growth.

This was a time when the captains of industry were often engineers, passionate about making the very best of products. This includes the founders of HP, Bill Hewlett and Dave Packard, the Varian brothers with Hansen and Grinzton at Varian Associates, Melville Eastham at General Radio and Howard Vollum, passionate about oscilloscopes, at Tek.

It was quite different from today's business leaders, who seem to care much more about the financial side of the business than the 'nitty-gritty'.

Tek focused on laboratory-quality oscilloscopes and quickly revolutionised the industry, driving the US oscilloscope leader DuMont out of the market.

Why 140kHz?

As readings go below about 0.3pF (difference frequencies <18Hz), the meter pointer increasingly shakes, as the pointer then responds to individual pulses from the multivibrator. So you wouldn't want the oscillator frequencies to be any lower.

Resonance at 140kHz occurs with values of L and C of 1136µH and 1136pF respectively. These values are sufficiently larger than the instrument's top range of 300µH and 300pF full-scale that the meter is acceptably linear. You wouldn't want it any less linear.

When the instrument was designed (about 1951), very few electronics laboratories had a frequency counter, so some other method was needed for calibration. While folk involved with radio transmitters had analog heterodyne frequency meters such as the BC-221, everybody had an AM radio receiver.

In most parts of North America, high-power clear channel broadcast stations were easily received at frequencies that were multiples of 140kHz, such as WLW (700kHz), WHAS (840kHz) or KMOX (1120kHz).

So, by running a wire from the buffer output to near the radio antenna, you could tune for a null beat note, and thereby set the fixed oscillator very accurately.

And if you could not pick up a clear channel station, you could probably receive a local station on 980kHz – the 7th harmonic of 140kHz. If you couldn't do that, the 5th harmonic from the T-130 could be nulled against the 7th harmonic from your trusty 100kHz quartz reference oscillator.

Careful and thoughtful design

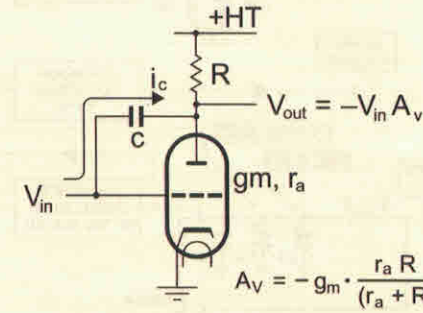
The full circuit is shown in Fig.2; it's quite complex for an LC meter. But it's clear that Cliff Moulton took care with the design to ensure the instrument is stable and accurate.

Many cheap capacitance meters employ the capacitor under test as the timing element in a multivibrator, and so interpret high leakage or shunt resistance as increased capacitance. But the T-130 substantially ignores resistance unless it lowers the Q enough to stop oscillation.

So the instrument either reads correctly or not at all. This is explained further in the panel detailing the oscillator design.

The Miller effect

The Miller effect is where any capacitance between the input and output of an inverting amplifying stage (triode, pentode, transistor, FET, op amp etc) makes the input impedance appear to include a much larger shunt capacitance.



In the circuit shown, Vout appears across the load R in parallel with the valve internal anode resistance r_a. The stage voltage gain for low values of C (ie, where the reactance of C is much larger than R) is $A_v = -gm \times r_a \times R \div (r_a + R)$. The negative sign denotes phase inversion.

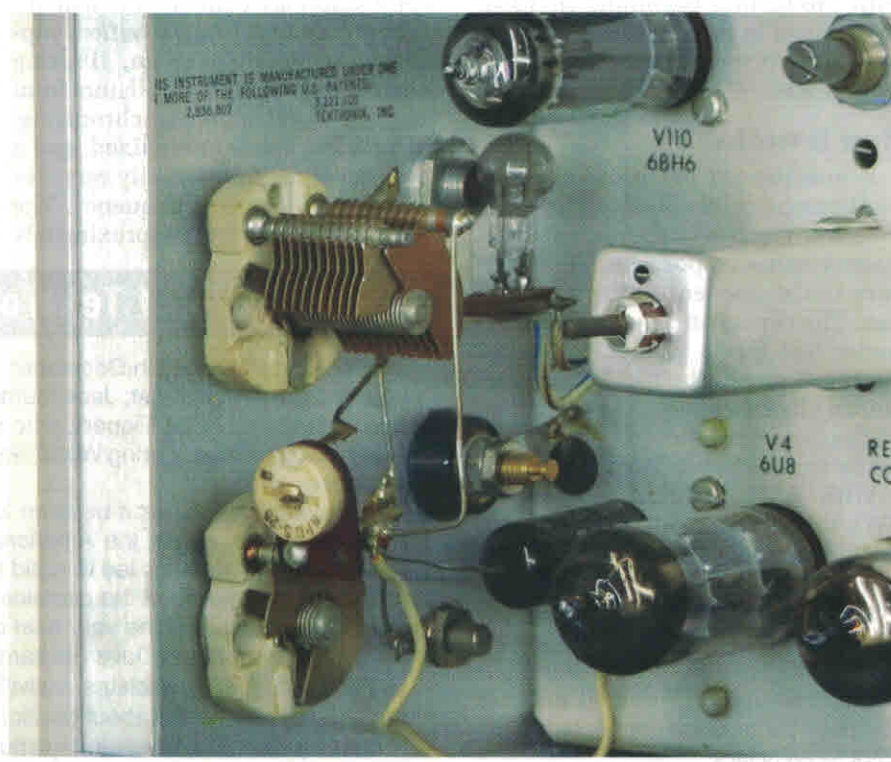
For typical triodes in typical circuits, Av is around -10 to -40. The capacitor then sees a voltage across it of $(V_{IN} + A_v \times V_{IN})$, ie, $V_{IN} \times (1 + A_v)$, and its current is thus increased by the A_v term.

Since the capacitor current is also included in the input current, the input impedance (the load on the previous stage) appears to include, in addition to the grid-cathode capacitance, a shunt capacitance of $C \times (1 + A_v)$ or approximately 10-40 times C.

The capacitor C comprises tube internal grid-anode capacitance, tube socket capacitance and any stray capacitance due to proximity of grid wiring to anode wiring.

The Miller effect with triodes, by its large capacitive load on any previous stage, typically causes the bandwidth of the preceding stage to be a small fraction of what it otherwise would be.

For more details, see John M Miller, Dependence of the input impedance of a three-electrode vacuum tube upon the load in the plate circuit, Scientific Papers of the Bureau of Standards, 15(351), pp367-385, 1920, USA.



A close-up of part of the variable oscillator section, incorporating V4 and variable capacitors C2-C5, as described in the panel labelled "An ingenious oscillator design".

The cathode interface layer

The nickel used in cathode sleeves before the early 1950s usually contained trace amounts (~0.05%) of silicon. During factory processing, and sometimes during early service, silicon diffuses to the surface and reacts with barium oxide. This forms a microscopically thin 'interface layer' of barium orthosilicate between the nickel sleeve and the oxide emission layer:

$$Si + 4BaO \rightarrow Ba_2SiO_4 + 2Ba$$

Pure barium orthosilicate has very high resistivity. As the interface layer is so thin and has free barium atoms within it, the resistance is low, and it does not initially affect tube operation. During tube operation, the high temperature required for emission drives diffusion of the free barium out of the interface layer, increasing the resistance.

Fortunately, cathode current causes barium atoms to diffuse back into the interface layer via an electrolysis process. The balance of these opposing effects results in interface resistance being quite sensitive to heater voltage. A 10% drop in heater voltage reduces cathode temperature by about 3.5% and interface resistance for a given cathode current by about 50%. The diffusion processes are very slow.

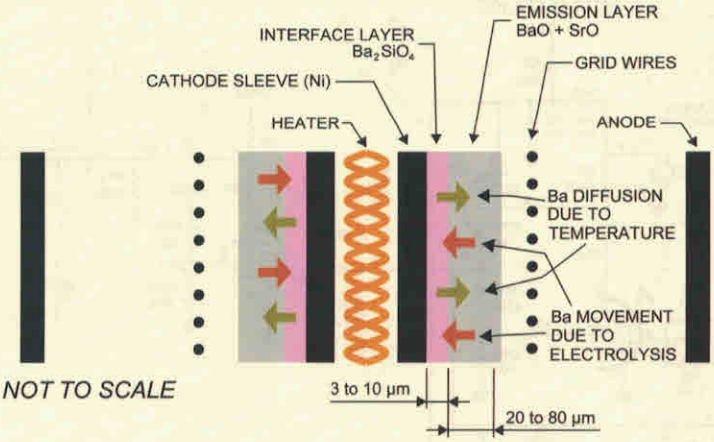
Interface layer resistance has the same effect as any resistance in series with the cathode; it increases cathode bias, possibly biasing the tube back to where the gain is lower, and also, by negative feedback, lowering gm. Note that although the tube may test low for gm, its emission can be entirely normal.

A tube with low gm due to the interface layer can usually be rejuvenated by operating it in a tube tester or rejuvenator with the maximum rated cathode current for a few days or more. This is not to be confused with rejuvenating a low emission tube by running it with a high heater voltage, which often doesn't work. And if it does, it's only for a while.

As the interface layer is so thin, it makes a pretty good RF bypass capacitor for its own resistance. Thus, you can easily detect the presence of an interface layer by measuring gm at an audio frequency and at RF, say 2MHz. The gm at 2MHz will be normal (unless the valve has some other fault), but the gm at audio frequencies will be lower.

Valves manufactured after about 1955 generally have high-purity cathode sleeves (less than 0.001% silicon), markedly reducing interface layer thickness and avoiding these problems.

Reference: M. R. Child, The Growth and Properties of Cathode Interface Layers in Receiving Valves, The Post Office Electrical Engineers' Journal, Vol 44[4], pp176-178, London 1952.



The variable oscillator operates under starvation conditions – very low anode and screen current – which results in a high gain. This means only 600mV peak-to-peak on the tuned circuit, even though the output to the buffer is quite high.

The low amplitude on the tuned circuit not only reduces the chance of forward-biasing junctions when in-circuit testing. It also means that the T-130 can be used to measure the Miller effect, as typical triode circuits under test will not be driven into overload. If you aren't familiar with the Miller effect, see the panel with the same name at upper left.

Running a valve under starvation conditions gives a high space charge density. The 6U8 triode-pentode variable oscillator valve (V4) has its heater voltage reduced by 1.5Ω resistor R405. This reduces the effect of any interface layer and reduces space charge, so oscillator drift with AC mains voltage better matches the fixed oscillator.

See the panel later in this article for an explanation of space charge density, and above for the interface layer.

The meter is pegged to the +150V rail and not ground as might be expected. This reduces the average DC voltage across the range capacitor, so that it's much less likely to develop leakage, and any leakage won't matter as much.

Bistable multivibrator

The circuit around V70 is called a bistable multivibrator by Tektronix but will be known to most people as a Schmitt trigger, after American Otto H. Schmitt, who invented it in 1934. Considerable positive feedback via common-cathode 5.6kΩ resistor R71 forces the pentode section, V70A, to operate in two fixed states – cut off, or drawing 4.2mA anode current.

When triode V70B is cut off, pentode V70A is on, due to the voltage divider R73 and R72 (470kΩ & 180kΩ respectively). 43V is dropped across R71 – a pentode cathode current of 7.7mA. Hence, the screen-to-cathode voltage is 110V, and the 6U8 data sheet shows that the screen draws 3.5mA at this voltage. Hence the anode current is 4.2mA (7.7mA - 3.5mA).

When the input from the filter rises above V70B's grid cut-off level (about 37V), V70B begins to turn on, reducing the voltage to V70A's grid. So V70A begins to turn off, dropping the voltage on R71. This turns on V70B harder, and the circuit immediately snaps over to V70B fully on with V70A cut off.

C73 compensates for wiring and socket stray capacities and ensures the snap action is fast.

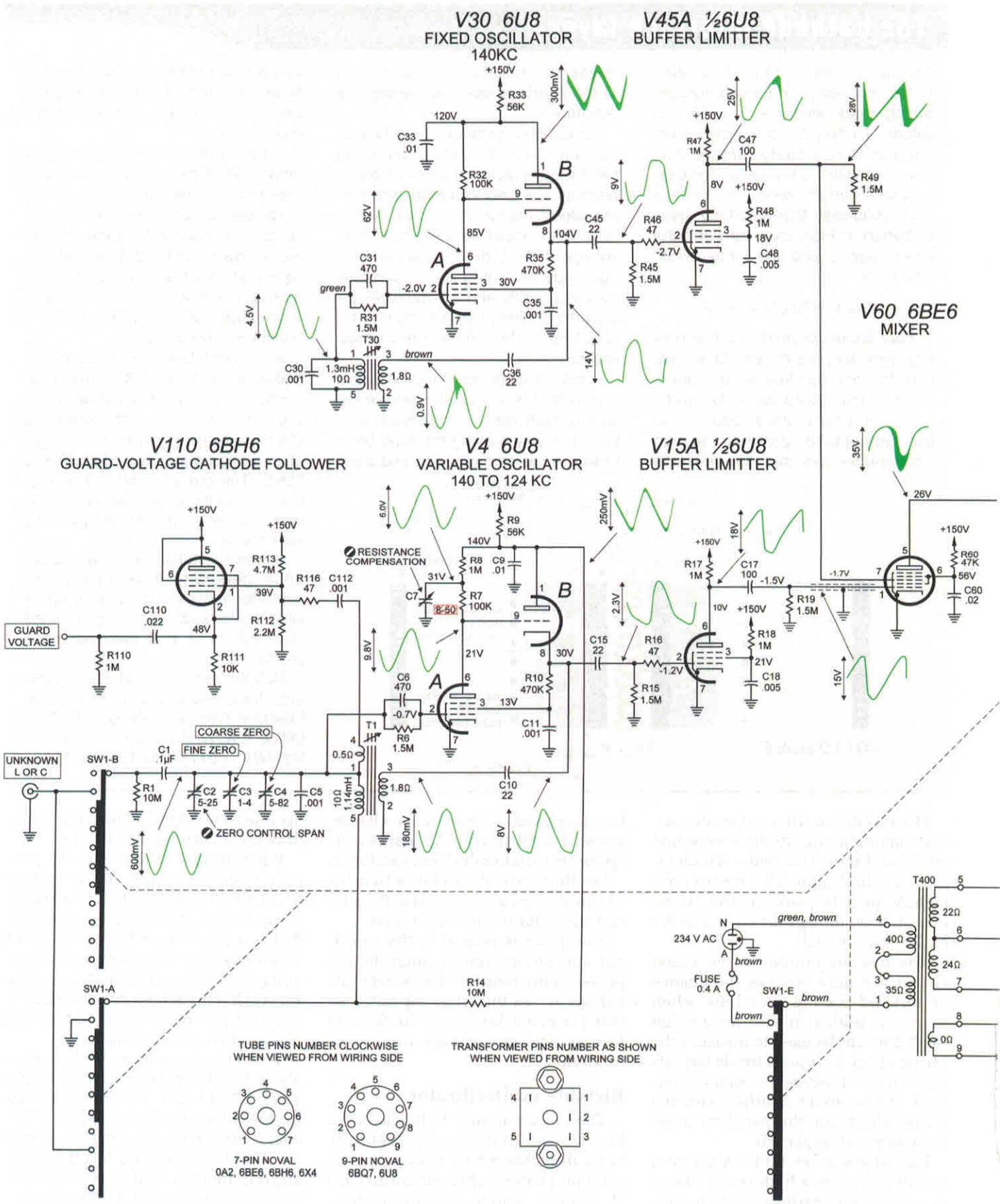
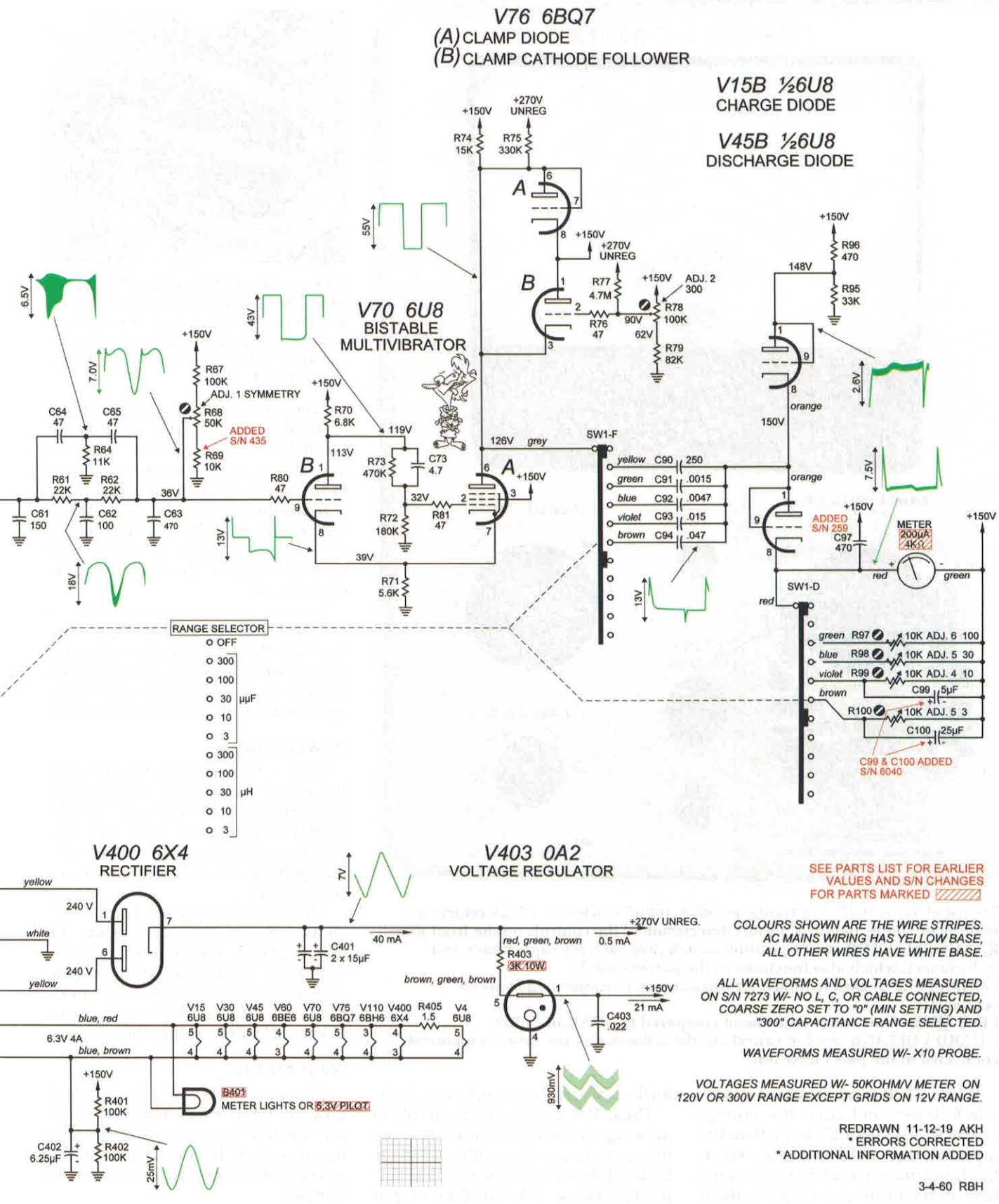


Fig.2: complete circuit diagram for the Tektronix T-130 LC meter.


V76 6BQ7
(A) CLAMP DIODE
(B) CLAMP CATHODE FOLLOWER
V15B ½6U8
CHARGE DIODE
V45B ½6U8
DISCHARGE DIODE
V70 6U8
BISTABLE MULTIVIBRATOR
+150V
+270V UNREG
R74 15K
R75 330K
R77 4.7M
R78 100K
ADJ. 2 300
R76 47
R79 82K
90V
62V
55V
43V
6.5V
7.0V
R67 100K
ADJ. 1 SYMMETRY
R68 50K
R69 10K
ADDED S/N 435
C64 47
C65 47
R64 11K
R61 22K
R62 22K
C61 150
C62 100
C63 470
36V
18V
13V
R70 6.8K
119V
113V
R73 470K
C73 4.7
R72 180K
R81 47
R80 47
32V
39V
R71 5.6K
126V grey
SW1-F
yellow C90 250
green C91 .0015
blue C92 .0047
violet C93 .015
brown C94 .047
R96 470
R95 33K
148V
orange
150V
2.6V
7.5V
ADDED S/N 259
C97 470
METER 200µA 4KΩ
red
green
SW1-D
RANGE SELECTOR
OFF
300
100
30
10
3
µµF
300
100
30
10
3
µH
green R97 10K ADJ. 6 100
blue R98 10K ADJ. 5 30
violet R99 10K ADJ. 4 10
brown C99 5µF
R100 10K ADJ. 5 3
C100 25µF
C99 & C100 ADDED S/N 6040
V400 6X4
RECTIFIER
yellow
240 V
white
240 V
yellow
7V
C401 2 x 15µF
40 mA
+270V UNREG.
red, green, brown
0.5 mA
R403 3K 10W
brown, green, brown
+150V
21 mA
C403 .022
930mV
V403 0A2
VOLTAGE REGULATOR
V15 6U8
V30 6U8
V45 6U8
V60 6BE6
V70 6U8
V75 6BQ7
V110 6BH6
V400 6X4
R405 1.5
V4 6U8
blue, red
6.3V 4A
blue, brown
+150V
R401 100K
B401
METER LIGHTS OR 6.3V PILOT
C402 6.25µF
R402 100K
25mV
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES FOR PARTS MARKED
COLOURS SHOWN ARE THE WIRE STRIPES. AC MAINS WIRING HAS YELLOW BASE, ALL OTHER WIRES HAVE WHITE BASE.
ALL WAVEFORMS AND VOLTAGES MEASURED ON S/N 7273 W/- NO L, C, OR CABLE CONNECTED, COARSE ZERO SET TO "0" (MIN SETTING) AND "300" CAPACITANCE RANGE SELECTED.
WAVEFORMS MEASURED W/- X10 PROBE.
VOLTAGES MEASURED W/- 50KOHM/V METER ON 120V OR 300V RANGE EXCEPT GRIDS ON 12V RANGE.
REDRAWN 11-12-19 AKH
* ERRORS CORRECTED
* ADDITIONAL INFORMATION ADDED
3-4-60 RBH
TYPE 130 L, C METER

Shown above is the T-130 testing an MSA 100pF capacitor, which returned a reading of ~98pF. Below is a short description of the controls on the front panel:
RANGE SELECTOR: an 11-position switch (five each for capacitance and inductance), which also functions as the power switch.
COARSE ZERO: used to adjust for capacitance in connecting leads or connectors.
FINE ZERO: finer range adjustment compared to COARSE ZERO.
GUARD VOLTAGE: used to cancel out the influence of any other component connected to the part under test.

While V70B is on, it acts as a cathode-follower and thus the voltage across R71 is about 2V more than the input voltage at V70B's grid. When the input from the filter is reversing later in the cycle and drops to about 35V, V70B starts to turn off, turning on V70A via the voltage divider formed by R72 and R73. V70A then raises the voltage across R71, forcing V70B further off and the circuit snaps back.

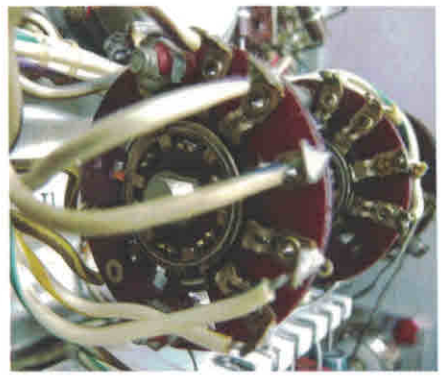
Thus, V70A snaps from cut-off to drawing a constant 4.2mA when the filter output rises above 37V, and snaps back to full cut-off when the filter output falls below 35V. The filter output considerably exceeds this range.

Guard cathode follower

V110 (6BH6) is a pentode connected to function as a triode cathode-follower. It takes a signal from the variable oscillator tuning coil and makes it available as a low-impedance (250Ω) guard signal on the front panel.

Since the voltage gain of a cathode follower is slightly less than unity, the cathode follower is driven from an over-wind on the tuning coil to compensate.

You can connect the guard output to the other end of any components connected to the item under test. Because there is then the same voltage at both ends of these components, the T-130 ignores them and gives a true reading.



This socket connects to the RANGE SELECTOR on the front panel. The visible ring connects to V70's anode, and the crimped lugs of the ring on the other side connect to the 230V AC mains input.

Power supply

V400, a 6X4, rectifies the AC from the power transformer to derive the unregulated 270V HT rail. A 0A2 (V403) regulates the 150V rail. The 0A2 is a cold-cathode gas-filled valve that performs the same function as a zener diode.

The valve heaters are run at 75V above ground. This is because the heater-cathode rating of the valves is only 100V. Since some cathodes are at or near ground, and some are at +150V, the heaters are run halfway between to keep all valves within their ratings.

Next month

That concludes the description of how the T-130 works. But what about the one that I purchased? What was wrong with it? How did I fix it? Don't worry; I have documented all the work in detail.

It will be described over the next two issues, starting with the aesthetic restoration and finishing up with circuit repairs and calibration.

Space charge capacitance

Valve cathodes are typically designed to emit electrons at about 2.5 times the rated maximum cathode current.

Taking the 6U8 pentode as an example, the rated maximum cathode current is 13mA, so the emission should be 33mA. In typical use, the sum of the anode and screen current would be around 4mA due to negative grid bias. The current is even less in the T-130 variable oscillator valve (V4).

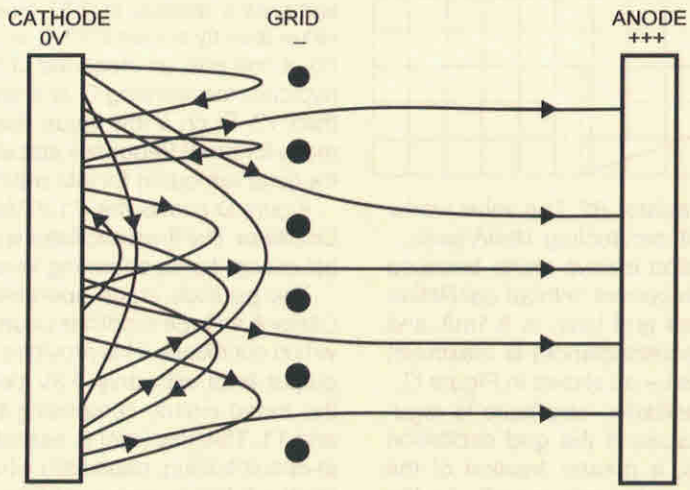
So if the cathode is emitting 33mA, and only 4mA is getting past the grid, what happens to the remaining 29mA? It goes back into the cathode!

In any conductor, conduction electrons are in continuous motion whizzing about at random velocity and direction. Collisions with atoms continually cause electrons to change direction. But at ordinary temperatures, practically none have enough inertia to escape the conductor due to the attraction of nearby nuclei – if electrons are not bound to particular nuclei, the nuclei must have a positive charge.

By heating the cathode, we raise the velocity of the conduction electrons so that some have enough inertia to escape. Any electrons leaving the cathode that are more than the number required to make up the anode current (which must return to the cathode via the external circuit) leave a positive charge in the cathode. So these excess electrons are inevitably sucked back into the cathode.

They follow individual parabolic paths outside the cathode, much like stones thrown up into the air returning to the ground. Negative grid bias encourages more of these electrons to give up and return to the cathode.

The cloud of electrons between the cathode and grid is called a "space charge" and tends to self-limit in local density, as space charge electrons repel more electrons leaving the cathode.



But it is considerably denser than the electron density between the grid and anode. The lower the anode and screen current, the denser the space charge. Our 6U8 example cathode always emits 33mA, but it may have up to 33mA returning.

The space charge electrons are in frequent contact with the cathode, and can be influenced by a varying electric field, so they constitute an electrical conductor, just as electrons do within a metallic conductor. So, we have a conductor – the space charge – near to, but not touching, another conductor – the negative grid. That's a capacitor! And it has a plate spacing less than the physical grid-cathode spacing.

The space charge capacitance typically adds 0.5-2.5pF to the inherent capacitance of the grid-cathode structure. This capacitance decreases with increasing grid bias (a more negative grid pushes the space charge further back toward the cathode) and increases with decreasing anode + screen current.

It increases about 10% for each 1% increase in heater voltage; hence, heater voltage variation due to AC mains variation is a significant cause of frequency drift in grid-tuned oscillators. An increase in heater voltage causes a decrease in oscillator frequency.

Shown above are a variety of homemade adaptors which can be connected to the UNKNOWN jack on the front panel. The largest one (second from the right) is a variable space capacitor for measuring permittivity – the degree that an insulating material increases capacitance between the plates over the capacitance obtained with air or vacuum spacing.

The fundamental requirements of a sinewave oscillator are:

- Something to set the frequency – a tuned circuit
- An amplifier to make up for the inevitable losses in the tuned circuit by feeding some of its output back to the tuned circuit – "tickling" the tuned circuit
- Feedback in-phase with the tuned circuit oscillation.
- A means to control the oscillation level

Often the amplifier was a single grounded-cathode valve that inverts the phase. This is corrected by connecting the tickler winding to give a second phase inversion.

Figure A shows a typical AM radio oscillator at mid-band. Let's take a look at how it works, and how the T-130 oscillators differ.

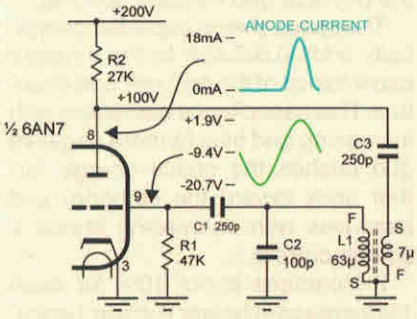


Figure A: a typical AM radio oscillator configuration. The T-130's implementation is shown at lower right in Figure D.

100pF capacitor C2 (comprising one section of the gang, a trimmer, and padder if used) and inductor L1 form the tuned circuit. The optimum oscillation voltage on the grid is 8V RMS, ie, 23V peak-to-peak. Grid current flows briefly on the positive peaks, clamping the tip of the peaks to about +1.9V. This forces the average grid voltage to be -9.4V by charging C1.

The 6AN7 triode section has a semi-remote cut-off, beginning at about -3V and fully cut off at -10V. Thus, significant anode current flows for only about 120° – as shown in Figure B.

250pF capacitor C3 and the tickler winding offer a low impedance, so almost all of the AC part of the anode current flows in the tickler winding, and only the DC part, about 3.8mA, flows

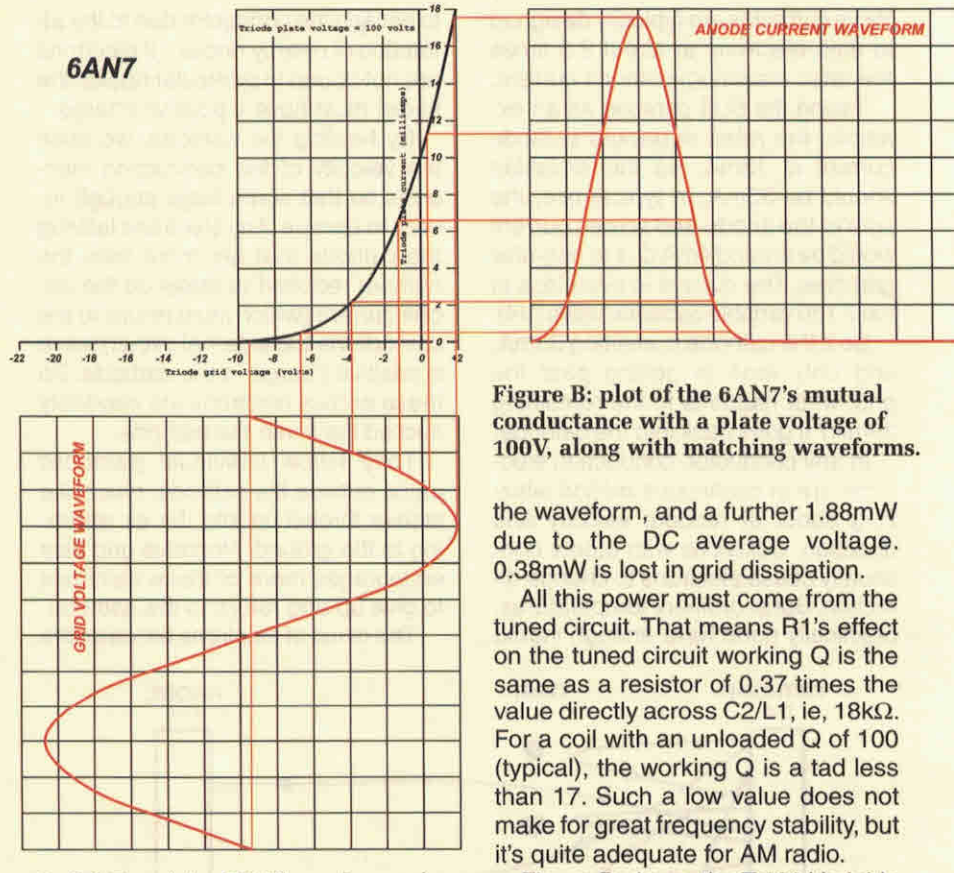


Figure B: plot of the 6AN7's mutual conductance with a plate voltage of 100V, along with matching waveforms.

in 27kΩ resistor R2. The valve works quite hard, conducting 18mA peak.

Oscillation always starts because the anode current without oscillation (and so no grid bias) is 5.1mA and gm (transconductance) is maximum at this level – as shown in Figure C.

The oscillation amplitude is regulated because if the grid oscillation increases, a greater fraction of the sinewave is beyond cut-off. As the grid will not allow any increase in the positive direction, the peak anode current is fixed at about 18mA. Still, the grid excursion goes further beyond cut-off, so the valve conduction angle decreases.

Therefore, the energy fed back via the tickler winding decreases, holding back the increase at the grid. This is called grid-controlled amplitude or grid stabilisation. Almost all LC valve oscillators use grid stabilisation.

R1 is typically 47kΩ. A much higher value is not used as it will let the circuit 'squeg', ie, multivibrate at a lower frequency and amplitude modulate the desired oscillation. R1 dissipates 1.36mW due to the AC component of the waveform, and a further 1.88mW due to the DC average voltage. 0.38mW is lost in grid dissipation.

All this power must come from the tuned circuit. That means R1's effect on the tuned circuit working Q is the same as a resistor of 0.37 times the value directly across C2/L1, ie, 18kΩ. For a coil with an unloaded Q of 100 (typical), the working Q is a tad less than 17. Such a low value does not make for great frequency stability, but it's quite adequate for AM radio.

Figure D shows the T-130 Variable Oscillator. The fixed oscillator is identical except for its operating level.

The pentode stage operates as a Class-A voltage amplifier under starvation conditions. This provides a high output level with only 0.3V peak on the tuned circuit, comprising C2-C5 and T1. This low level is essential for in-circuit testing, especially when using the T-130 to measure Miller effect capacitance.

The pentode is biased not by grid rectification but by its own space charge. The grid never goes positive and never draws energy from the tuned circuit. Since the energy dissipated in 1.5MΩ resistor R6 comes from the pentode space charge and not from the tuned circuit, the tuned circuit operates at its unloaded Q.

Since the grid never goes positive and doesn't rectify, the circuit cannot squeg no matter how high the grid resistor (R6) is.

For an iron dust core of the size used, the Q is probably about 150-200. It will be lowered by resistance in the circuit under test, of course, but

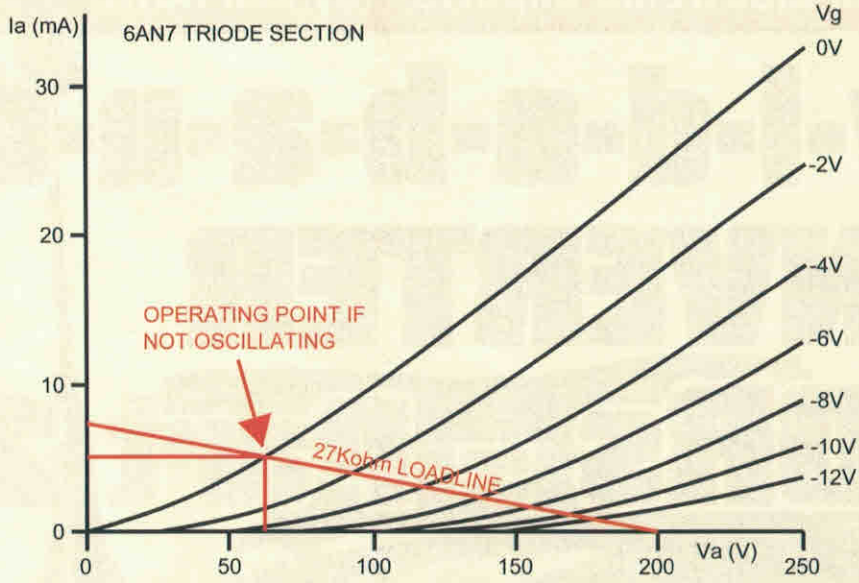


Figure C: plot of the 6AN7's anode voltage versus anode current for various grid bias amounts. The 27kΩ is the load connected to the plate of the 6AN7 (R2 in Figure A).

will always be above 30, and usually well above. The low-impedance tickler winding is loosely coupled and 'looks into' a small capacitance (22pF capacitor C10). So the tickler has no significant effect on Q.

The triode only conducts on positive peaks, as C10 can be charged by the cathode but not discharged by it. The triode conducts for only about 80°. That's why the signal at the cathode is half what it is at the grid. The cathode current peaks at 280µA; during the peaks, 120µA flows in C10, 120µA in C15, and 36µA in R19. The pentode current averages 110µA. The 6U8 is far from being worked hard.

If the oscillation level increases, C10 and C15 will charge up a bit more so that the signal on 470kΩ resistor R10 remains at about 6V peak-to-peak. But the greater swing on the grid means that the triode conduction angle must decrease. So less energy is fed back to the tuned circuit.

Unlike most LC tuned oscillators, this circuit is cathode-regulated. By using a triode-pentode with cathode stabilisation, we get a very stable oscillator. Considerable negative DC feedback via R10 holds the DC working point close to the designed level regardless of valve aging.

Ideally, signal feedback in an oscillator should be in-phase. What happens if it is not precisely in-phase? The first effect is that slightly more amplifier gain is needed. That's unimportant; plenty of gain is available, and the circuit will self-adjust anyway. The second effect is important in this application: it changes the frequency slightly.

Say the feedback is slightly late. By holding back the rate of change in the tuned circuit, the frequency drops slightly. Conversely, if the feedback is a little early, the rate of change is reinforced, and the frequency increases.

The ordinarily high Q of the tuned circuit strongly resists this influence over frequency. This means that if Q is lowered, say by a resistance across the tuned circuit, the frequency will change in the direction pulled by the feedback phase.

The pentode output is phase-inverted and of high impedance; about 800kΩ. Variable capacitor C7, together with stray wiring capacitance and the grid-anode capacitance of the triode section (~2pF), causes an additional phase lag of about 80°. So the signal at the triode grid, and the cathode, is lagging by 260°.

Most of the triode output voltage is dropped across C10, which means that C10 causes a phase lead, of about 80°. So we are back to approximately 180°, and, like many oscillator circuits, the situation is corrected by the phasing of the tickler winding (between pins 2 & 3 of T1).

Part of the calibration procedure is to adjust the phase by adjusting C7 so that the frequency doesn't change when two different test resistances are connected across the UNKNOWN terminals. This means that the feedback is precisely in-phase, and the T-130 reading is independent of any shunt resistance when in-circuit testing – within reason. Clever, eh? Too much loss stops oscillation.

Correct adjustment of C7 also means that the variable oscillator is maximally tolerant of contact resistance in the RANGE SELECTOR switch, improving frequency reset-ability. SC

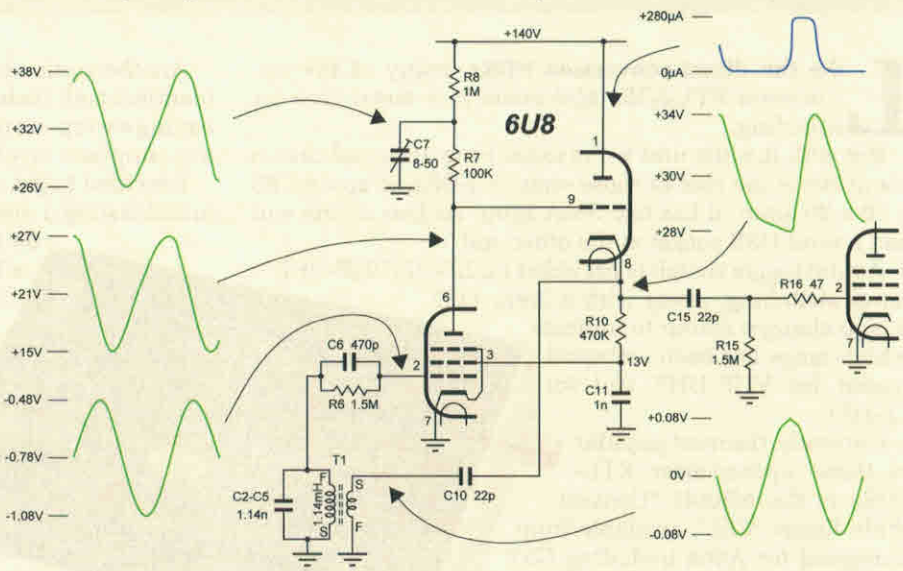


Figure D: the variable oscillator configuration used in the T-130 uses a 6U8 triode pentode.

New w-i-d-e-b-a-n-d UPCONVERTER RTL-SDRs – Part 2

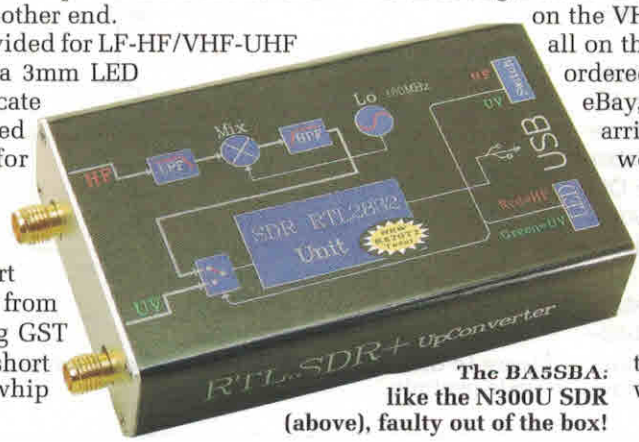
Last month, we described two of the latest compact wideband RTL-SDRs, which used direct conversion for reception below 25MHz. This time we're reviewing some of the larger units, which have inbuilt upconverters for improved reception below 25MHz.

Like the direct-conversion SDRs, many of the upconverter RTL-SDRs also come in a metal case for shielding.

But with the first unit we're examining, its metal case is about twice the size of those simpler SDRs, at around 83 x 50 x 20.5mm. It has two SMA input sockets at one end and a mini USB socket at the other end.

A mini toggle switch is provided for LF-HF/VHF-UHF range switching, along with a 3mm LED which changes colour to indicate which range has been activated (green for VHF-UHF, red for LF-HF).

Currently, the most popular of these upconverter RTL-SDRs is the N300U "Convert Wide Range SDR", available from Banggood for A$68 including GST and postage. It comes with a short USB cable and a coil-loaded whip 'test antenna'.



The BA5SBA: like the N300U SDR (above), faulty out of the box!

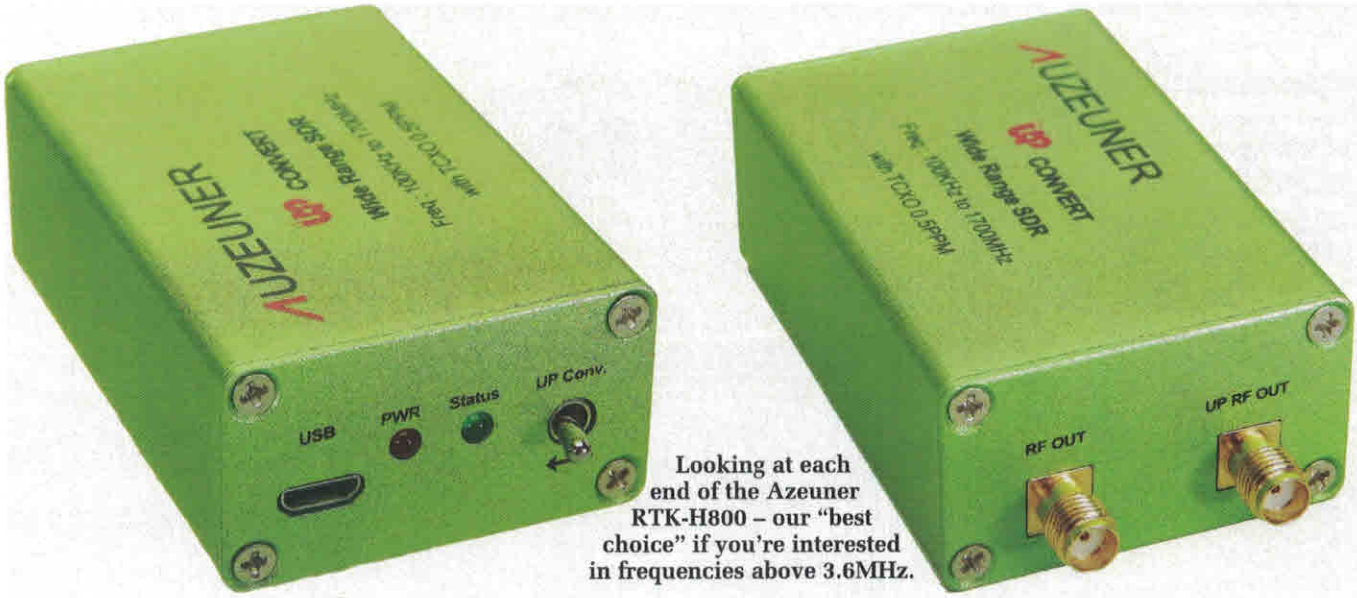
Another option is the BA5SBA. This appears to be almost identical both inside and out, apart from the BA5SBA unit having a wrap-around dress panel. It is available from various suppliers on eBay, for about A$75.

I decided to get one of the N300U units first, but during initial testing, I discovered that while it worked quite well on the VHF-UHF range, it did not work at all on the LF-HF upconverter range. So I ordered a BA5SBA from a supplier on eBay, and began testing it as soon as it arrived. Strangely enough, it didn't work on the LF-HF range either!

I went through all of the information I could find on the web regarding these upconverter SDRs, in case I was not using them correctly.

But after a lot of testing and retesting, I had to conclude that they were both faulty.

That was when I opened up both



Looking at each end of the Azeuner RTK-H800 – our "best choice" if you're interested in frequencies above 3.6MHz.

units to check for faults. As you can see from the photo overleaf, both have two PCBs, with the upper PCB being a DVB-T dongle board just like the one in the two compact RTL-SDRs we looked at last month. The larger PCB underneath has the extra circuitry for the upconverter plus the two SMA input connectors, the range switch, indicator LED and mini-USB socket.

I probed around with a DSO and found that in both cases, the 100MHz local oscillator wasn't producing any output when the range switch was set to for the LF-HF range.

I did find that they both worked fairly well on the VHF-UHF range, by the way. Frustrating! I tried contacting both suppliers to see if they were able to provide replacement units, but in both cases, all they were prepared to do (eventually) was offer me a partial refund.

That simply isn't good enough, given that these products didn't do what they claimed to at all. But it's all too common these days when buying from overseas.

So I ordered yet another upconverter RTL-SDR; one which, according to the pictures on the eBay supplier's website, looked as if it was on a completely redesigned single PCB.

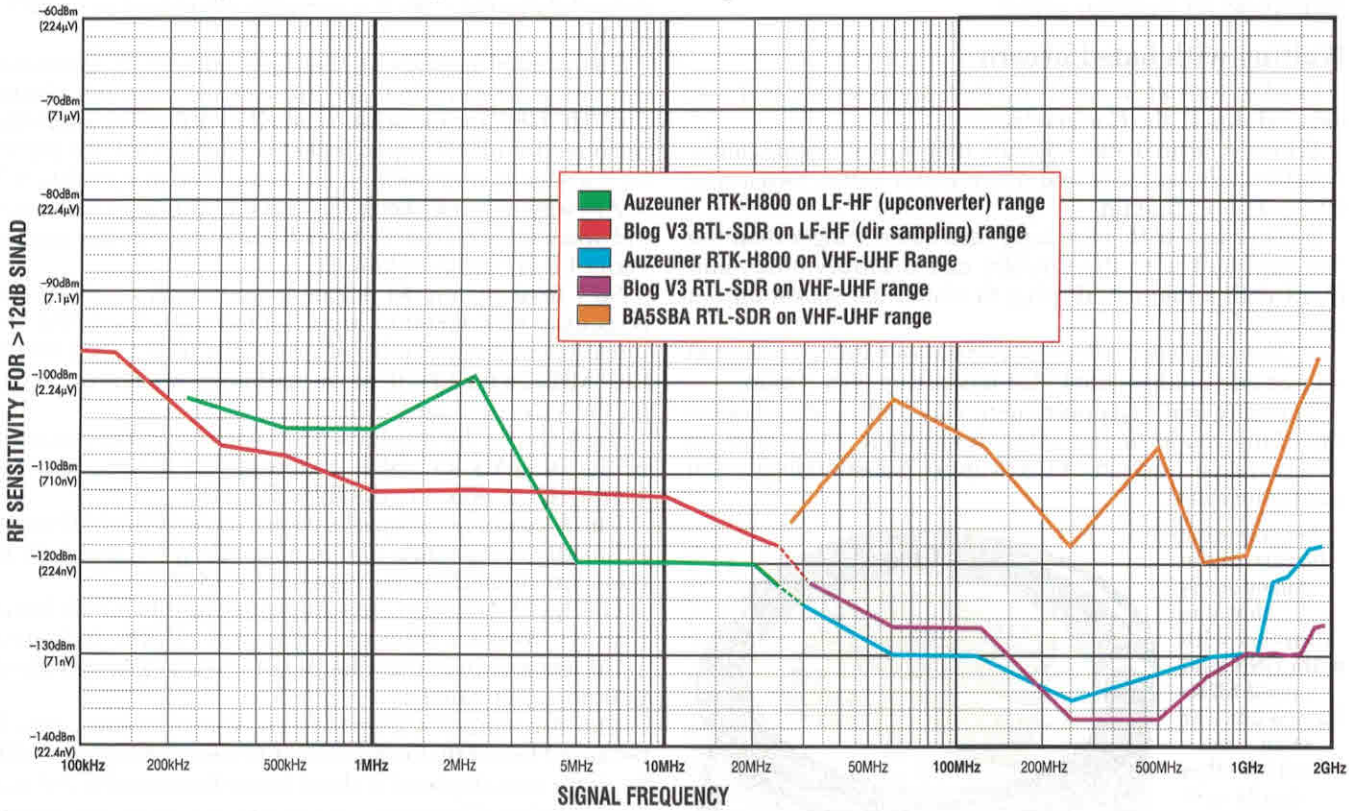


Fig.1: a comparison of the sensitivity (minimum signal level needed for a reasonable reception signal-to-noise ratio of at around 12dB) for three SDRs over a wide range of frequencies. Lower figures (ie, higher negative dBm values) indicate better performance.

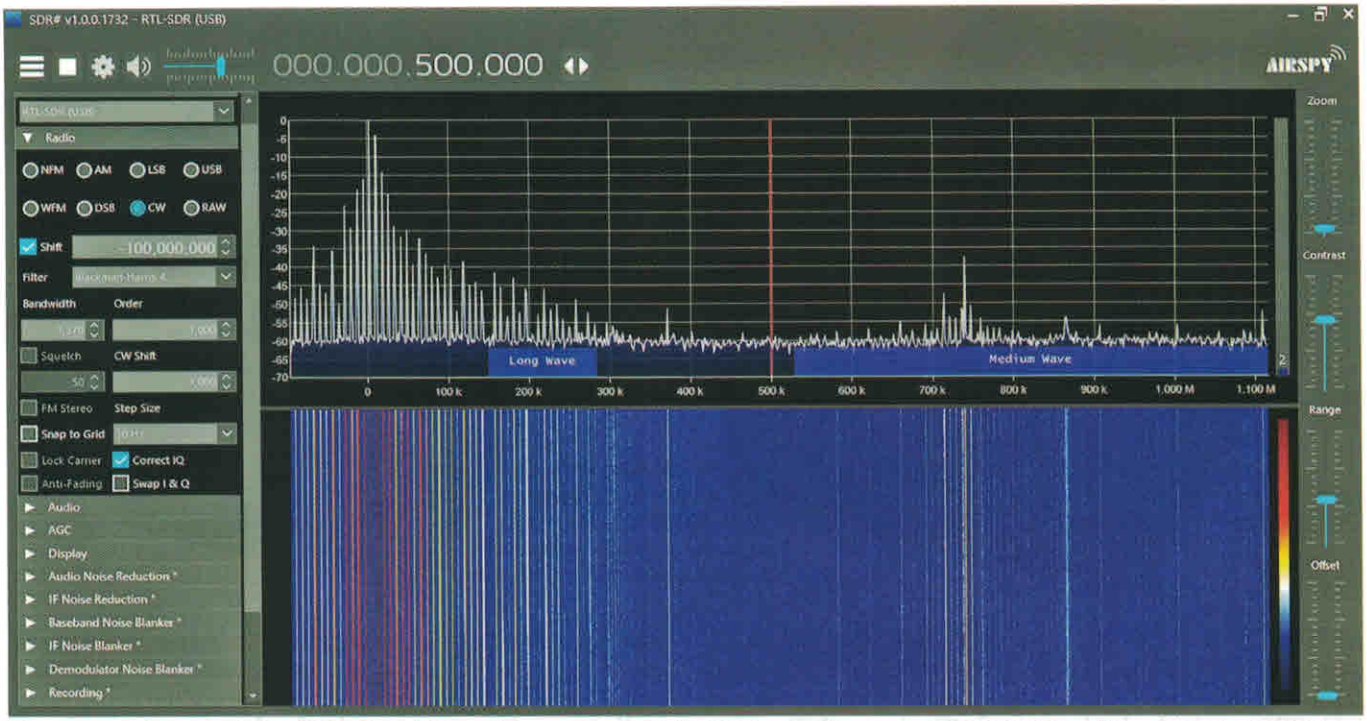


Fig.2: a spectral analysis of the signal from the Auzeuner RTK-H800 over the range of 0-1.1MHz with no input signal (its input was terminated with 50Ω). This should be a flat line but instead shows a field of spikes which interfere with the reception of AM broadcast band signals and longwave transmissions. For this reason, the Blog V3 RTL-SDR described last month is better for low-frequency AM reception.

This was the Auzeuner RTK-H800 or N300_V2, which came from eBay seller cybereveryday (2835) and was priced at A$78.31 with free postage (it's also available on AliExpress for a similar price).

Waiting with bated breath

I had to wait a few weeks for that one to arrive, as it was delayed due to the Coronavirus.

When it turned up, I found that it was significantly smaller than the other two upconverter SDRs, measuring 62.5 x 41.5 x 23.5mm.

It also came with a 3m long USB cable; longer than the one supplied with the Convert and BA5SBA units, and fitted with a micro-USB plug to match the socket on the unit itself.

As I had expected, all its components are indeed mounted on just one double-sided PCB measuring 60 x 39mm.

The only real disappointment was finding that despite the claim made in the sales description, there was no 'thermal tape' under the PCB to improve heat transmission out to the case.

Another nice feature of the Auzeuner is that it is supplied with a 3m USB lead – most SDRs have a 2m – or even 1.8m – which often simply isn't long enough!

Like all of the other SDRs we have looked at lately, the Auzeuner uses the combination of a Rafael Micro R820T2 programmable tuner IC and a Realtek RTL2832U COFDM demodulator chip. So it is correctly described as an RTL-SDR.

The printed legends on the input end of the Auzeuner unit are a bit puzzling. As you can see from the photo, the VHF-UHF input socket is labelled 'RF OUT' while the upconverter LF-HF input socket is labelled 'UP RF OUT'. So it seems that something has been "lost in translation"!

Anyway, a quick check showed that this unit definitely did work on both the VHF-UHF range and on the upconverter LF-HF range (whew!).

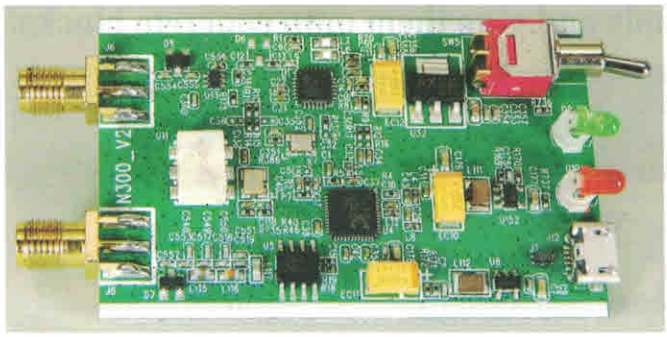
So I fired up my RF signal generator, hooked up the Auzeuner RTK-H800 to my PC fitted with the SDR# application, and ran a series of sensitivity tests from 100kHz to 25MHz on the LF-HF range, and from 30MHz to 1.7GHz on the VHF-UHF range.

Fig.1 shows the results, which also shows the response of the Blog V3 RTL-SDR reviewed last month, and the VHF-UHF response of the BA5SBA SDR.

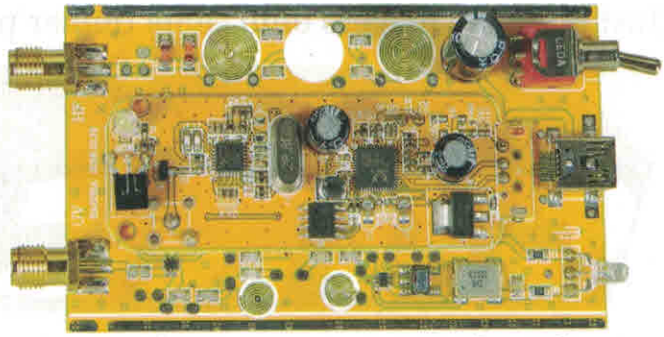
The Auzeuner unit's performance on the VHF-UHF range is broadly comparable to that of the Blog V3, and both of them are 10-20dB better than the BA5SBA.

On the LF-HF range, the Auzeuner unit is 3-7dB better than the Blog V3 between 4MHz and 25MHz, but about 12dB less sensitive than the Blog V3 at 2.2MHz and about 2dB poorer at 230kHz.

The Auzeuner's response is not shown below 230kHz because I found that measurements were getting quite difficult (or meaningless) at these lower frequencies due to a large number of spurious 'spikes' present in the Auzeuner's output, even when the upconverter input was connected to a shielded 50Ω termination.



The Auzeuner is made on a single PCB (as distinct from many others which have two sandwiched boards).



In this pic of the BA5SBA, you can just make out the "piggy backed" PCB sitting above the middle of the lower board.

This is shown in Fig.2, which covers an effective frequency range 0Hz to 1.1MHz.

Summary

As Fig.1 shows, the sensitivity of the Auzeuner RTK-H800 upconverter RTL-SDR is quite impressive from 30MHz to 1.15GHz.

It needs a signal of just -125dBm (126nV) or less for an SNR (signal-to-noise ratio) of better than 12dB. It only becomes a little less sensitive at frequencies above 1.15GHz, but still only needs a signal of -118dBm (282nV) to achieve an SNR of 12.7dB at 1.65GHz.

This is quite comparable with the performance of the Blog V3; it is actually about 3dB more sensitive over the range of about 30MHz to 180MHz.

It's on the LF-HF range that the comparison becomes a bit more confusing.

The Auzeuner is equal to or better than the Blog V3 from 3.6MHz to 25MHz, with the gap between the two being about 8dBm at 5MHz and just on 7dBm at 10MHz.

But below 3.6MHz, the sensitivity of the Auzeuner unit is worse than that of the Blog V3, with the gap between the two widening to about 12dBm at 2.2MHz. Still, even then its sensitivity is quite reasonable, at -99.5dBm or 2.4uV.

Presumably, it's the Auzeuner's upconverter that is responsible for the excellent sensitivity of 120dBm (224nV) between 5MHz and 25MHz. But it also seems that it is to blame for the worse sensitivity below 3.6MHz, and the forest of spikes below 300kHz.

This makes it hard to decide which is better for LF-HF reception – the Blog V3 with its direct conversion approach, or the Auzeuner RTK-H800 with its upconverter.

I guess it boils down to the part of the spectrum you're most interested in.

If you're mainly interested in reception below 3.6MHz, go for the Blog V3 (see last month).

However, if you're more interested in reception at frequencies above 3.6MHz, the Auzeuner RTK-H800 is the better choice. SC

A size comparison, not far off life size, between three of the units: the BA5SBA at the top, the Auzeuner RTK-H800 in the centre and the Blog V3 (which we looked at last month) at the bottom.

Useful Links

- www.airspy.com – the best source of the SDR# application
- www.hdsdr.de – source of the HDSDR application
- www.rtl-sdr.com – an excellent source of information on RTL-SDR
- www.rtl-sdr.com/big-list-rtl-sdr-supported-software
- www.sdr-radio.com/downloads
- www.secomms.com.au – Australian supplier of the RTL-SDR Blog V3
- https://zadig.akeo.ie – the source of Zadig, the Windows generic USB driver installer (needed by most SDR software)

Just bung the drivers onto some timber panels and glue them onto concrete blocks!

CONCRETO Speaker System

We were tempted . . . very tempted . . . to call these the greatest "ROCK" speakers ever. But that pun would fall a bit flat because these speakers are not rock – they're concrete! More specifically, their "enclosures" are stock standard concrete building blocks – the type you'll find at very low cost in just about every hardware store. Intrigued? Read on . . .

Want to build a pair of speakers, but don't have the skills, tools or time to build proper boxes for them?

No worries. We have the solution for you! Just bung the drivers into some timber panels and glue them onto concrete blocks. It might sound like an odd thing to do, but you'd be surprised how well it works.

This bookshelf speaker system gives punchy and clean sound, and it's a lot of fun to build, with excellent bass and treble out of one tiny full-range driver, plus a subwoofer or two.

by Allan Linton-Smith

For just a few dollars more, you can get a Class-D amplifier module to drive both, with line inputs and Bluetooth wireless audio support.

Concrete is actually an excellent material to make loudspeaker enclosures from because it's very stiff and it's very 'dead' – you don't have to worry about it resonating at all and 'colouring' the sound. As a bonus, concrete blocks (also known as concrete bricks, Besser blocks and breeze blocks) are ***cheap,*** readily available and have four square sides already pre-assembled.

The pair of "bookshelf" speakers, housed in half-blocks. They'll give a good account of themselves "as is" but team them up with the full-block subwoofers and you won't believe how good they sound for such a tiny investment. Rock on!

At 190 x 190 x 190mm, the half-block bookshelf speakers are exactly half the size of the subwoofers because the latter are built in a standard 380 x 190 x 190mm concrete block. There are two huge advantages in using concrete blocks as enclosures: (a) they're dirt cheap and (b) they cannot flex or move to colour the sound in any way. You might say they're as solid as a (ahem!) rock . . .

This is definitely not a new idea. Building speakers became a bit of a fad in the 1950s. At the time, concrete was considered by many to be the ideal material from which to make speaker enclosures.

Concrete speakers have faded in popularity since then, but are seeing a bit of a resurgence. Besides being practical, they also look pretty interesting, especially with nicely-finished, routed timber front panels.

The concrete also helps to improve overall efficiency, transmitting less than 25% the amount of sound energy that a comparable wood or MDF enclosure would.

Many people prefer to have smaller speakers, but they often compromise on sound.

These ones emit a solid bass and have clarity which you will fall in love with immediately. They also have a really smooth sound, partly because of the lack of resonance and partly because of our choice of drivers.

In keeping with the idea of simplicity and cheapness, we've simply glued the front and rear panels onto the $3.50 concrete blocks with silicone sealant, and we've used a coaxial main driver so that no separate tweeter is required. That also eliminates the need for a crossover network.

Another big advantage of using a single driver is its phase coherence; that is, its ability to reproduce all frequencies with mostly the same phase.

This produces a very realistic reproduction of the original recording for voice, instruments or complex orchestration. It is essential for accurate 'soundstaging' (positioning of each instrument).

Features & specifications

- Frequency response: 90Hz-20kHz, ±6dB
- Distortion: <2%, 85Hz-2.7kHz (0.8% @ 1kHz)
- Bookshelf efficiency: 91.5dB @ 1W, 1m
- Subwoofer efficiency: 88dB @ 1W, 1m
- Power handling: 2x15W (Bookshelf), 2x50W (Subwoofers)
- Impedance: 8Ω (Bookshelf), 6Ω (Subwoofers)
- Low cost - estimated <$200 to build all four units

The small cone is very accurate in the upper and mid-range, but you will also get to hear pipe organ pedals and bass drum kicks if you build the extra subwoofers.

They are so cheap to make, why not build two for better bass?

Driver choice

We considered three different full-range drivers for the Bookshelf speakers. Table 1 shows a comparison of these units. We chose the

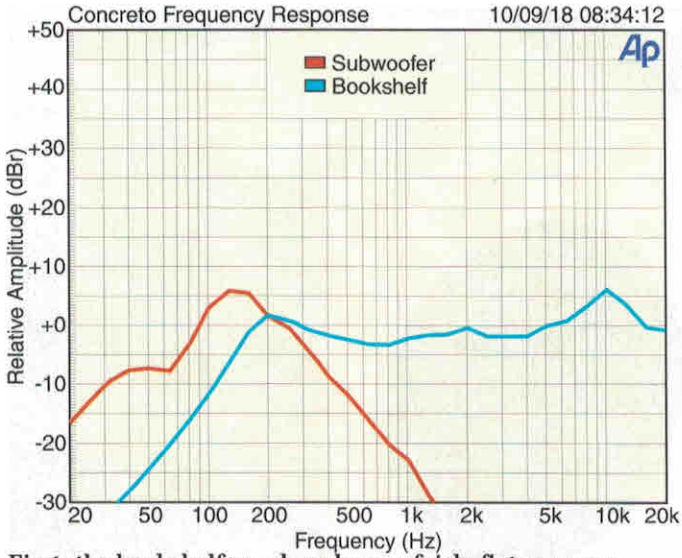


Fig.1: the bookshelf speakers have a fairly flat response above 150Hz; the subwoofers fill in below 200Hz where the bookshelf response drops off.

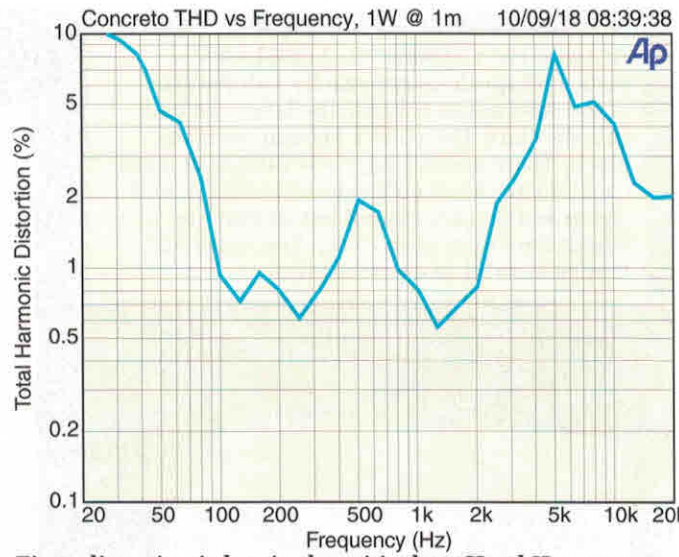


Fig.2: distortion is low in the critical 100Hz-2kHz range which contains a lot of human voice information as well as many musical instruments.

Altronics C0626 on the basis that they are a lot cheaper than the Fostex drivers and only have slightly less bass, slightly higher distortion and slightly lower efficiency.

In other words, they are almost as good for about 1/4 the price.

The Jaycar drivers are cheaper again, but are much less efficient, so given their relatively low 15W power handling, you'd struggle to get decent volume out of them. So that was why we didn't end up using them, and didn't bother measuring their actual frequency response or distortion level.

However, we are using Jaycar 125mm drivers for the Subwoofers, cat no CW2192. They are also excellent value at $29.95 each (retail price, including GST) given their 50W power handling, decent efficiency of 88dB @ 1W, 1m and low resonant frequency of 67.6Hz.

In fact, in the enclosure we've designed, they give some output down to about 35Hz, which is impressive given their small size.

Performance

The frequency responses of the two speaker cabinets are shown in Fig.1. Here, "Bookshelf" (the blue curve) refers to the smaller cube-shaped enclosures which house the midrange drivers with coaxial tweeters, while "Subwoofer" (the red curve) refers to the taller ported enclosures with the larger woofers.

The Bookshelf speakers are pretty flat from 150Hz to 20kHz, with a moderate peak at 10kHz and a roll-off in response below about 180Hz. You can see why we decided to build the subwoofers; they extend the bass response considerably, down to around 65Hz, with a bit of a shelf from 40-65Hz. This means that really low bass won't quite be 'full', but you'll at least hear something down to about 35Hz.

Importantly, the system also provides low distortion sound, as shown in Fig.2. THD is well under 2% from 100Hz to 2.5kHz and less than 0.8% at 1kHz. It is reasonably efficient, delivering 91.5dB at 1W/1m/1kHz.

You may think that it is only suitable for small rooms, but they produced a considerable amount of sound in our warehouse with only a few watts driving them.

Regardless, if you want good quality sound at reasonable listening levels, these will not fail to impress.

A nice little Class-D amplifier module is ideal for driving these speakers, for example, one of those I reviewed in the May 2019 issue of Silicon Chip (**siliconchip.com.au/Article/11614**).

They certainly could also be driven by one of our more powerful/higher fidelity audio amplifiers, such as the Ultra-LD Mk.4 (August-October 2015; **siliconchip.com.au/Series/289**) or the SC200 (January-March 2017; **siliconchip.com.au/Series/308**).

These Concreto speakers will provide many hours of wonderful listening at a tiny fraction of the cost of a fully-built high-end hifi system. The sound is even more satisfying, knowing that you have built something a bit unusual!

Listening tests

All the staff in the Silicon Chip office were amazed that

	Fostex FE103En	Altronics C0626	Jaycar CS2310
Price per pair (approximate)	$150	$34	$25
Impedance	8Ω	8Ω	4Ω
Rated efficiency (dB @ 1W, 1m)	89	95	83
Free-air resonance	83Hz	120Hz	122Hz
Vas (litres)	6	?	3.3
Rated frequency response	83Hz-22kHz	120Hz-20kHz	90Hz-18kHz
Measured response (±5dB)	60Hz-15kHz	70Hz-15kHz	
Measured THD+N (1kHz, 90dB)	0.45%	0.65%	
Measured SPL @ 1W, 1m	92.5dB	90dB	

Table 1: full-range driver comparison. All three are rated at 15W, employ a ferrite magnet and suit a 93mm diameter hole cut-out.

these little speakers with 100mm (4in) drivers could produce such a huge sound. Not only that, but the realism, separation and positioning of the instruments and singers are truly first class.

When using a quality DAC and amplifier, the music was fabulously rich, and we were able to pick out each instrument as if they were there.

But don't believe us; you be the judge. Build it and enjoy the rewards of listening to a concerto... err... Concreto. It will be worth the effort!

Construction

Select your concrete bricks carefully. We bought ours from Bunnings, and selected the ones with the smoothest surfaces and minimal cracks and chips. You might want to spend a few extra dollars and buy some spares, because they are heavy and are easily dropped or bumped. Make sure they are completely dry (especially if you take them from your backyard); otherwise, the silicone sealant won't adhere too well.

For the subwoofer bricks, decide which side is to be the front and the back, mark them with a pencil and then grind or chisel 2-3mm from the back of the centre piece as shown in Fig.3. We used an angle grinder fitted with a diamond blade, but you can also use a "scutch" or masonry chisel.

Check how much you're taking off with a straightedge, and use a credit card as a feeler gauge. When finished, you should be able to hold the straightedge across the front surface of the brick and slide the credit card between it and the centre section, where you removed the material.

Timber panels

We used premium pine planks, dressed all-round (DAR), 184mm x 1.8m x 19mm thick. You can then easily cut these to 184mm and 390mm lengths to make the panels for the Bookshelf and Subwoofer speakers respectively.

You may be able to get the hardware store to cut these

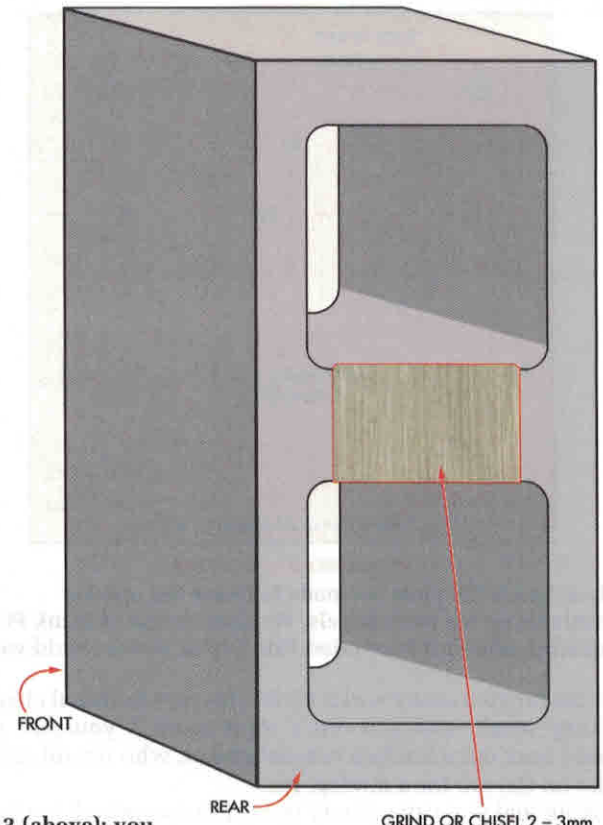
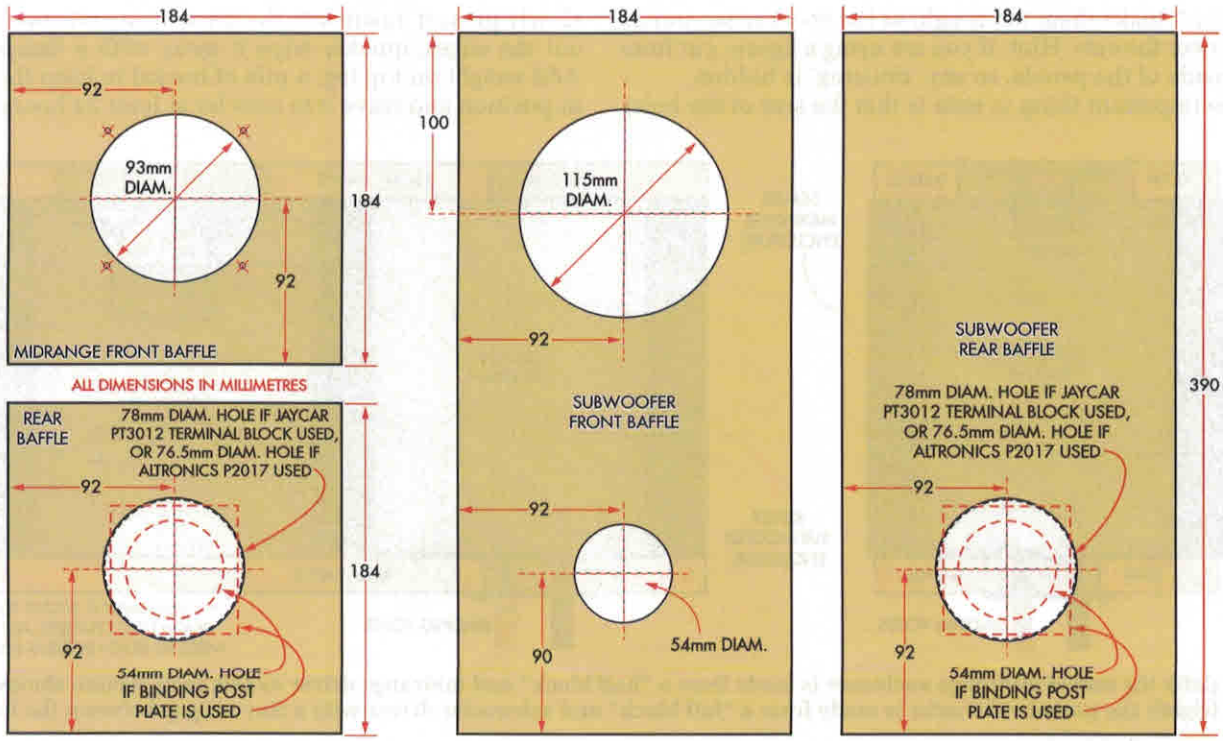


Fig.3 (above): you will need to remove some of the cross connector where the rear panel sits to allow air to flow from the driver to the port. It doesn't have to be pretty because it's covered by the rear panel.

Fig.4 (below): dimensions of the front and rear baffles for both the midrange and subwoofers. We used 19mm DAR pine but many other timbers could be used.



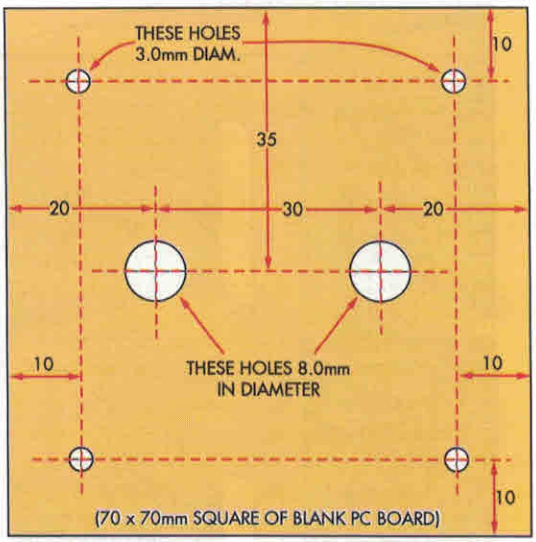


Fig.5: here's the plate we made to house the speaker terminals on the back panels. We used scraps of blank PCB material; aluminium or other thin (rigid) plates would work!

pieces for you; many will do it for free, or a nominal charge. If they won't, and you don't want to do it yourself, you could seek out a kitchen cabinet maker, who would surely take on the job for a modest fee.

Note that you can use any type of timber which is 19mm thick or more, such as MDF or plywood. But we think the DAR pine looks pretty special in this application.

Assembly is pretty easy, but do not rush it and allow plenty of time between steps so that you don't make any mistakes.

Once you've cut the panels to size, the next step is to cut the holes, as shown in Fig.4. Ideally, you should use a hole saw for the port holes in the Subwoofers, as they are fully exposed

You could use a jigsaw to cut the other holes, as long as you don't make them too rough, as the speaker surrounds will cover the cuts. Hint: if you are using a jigsaw, cut from the inside of the panels, so any 'bruising' is hidden.

One important thing to note is that the size of the holes in the rear panels vary depending on which type of speaker terminals you'll be fitting. If you're building the home-made speaker terminal panels from a piece of blank PCB laminate and a pair of binding posts, cut 54mm holes. If you're using the Jaycar PT3012 terminals instead, make the holes 78mm diameter, or for Altronics P2017, 76.5mm diameter.

Once you've made all the cut-outs, sand the port holes nice and smooth, and clean off any burrs from the other holes. You might like to dress the edges with a router or plane. This makes the speaker look much better, although it isn't absolutely necessary.

Next, if you didn't splurge on the pre-built speaker terminals, make up the connector plates from blank PCB material, and standard binding posts mounted 30mm apart.

Make sure you've sanded away any imperfections in the panels, then paint, stain or lacquer the panels. We used a red stain and a lacquer finish. Allow them to dry completely, and you are ready to assemble everything.

Assembly

This is pretty straightforward; you just need to proceed carefully, so you don't damage anything; especially the delicate speaker cones and surrounds.

Start with the backs of the enclosures. Dust off the concrete blocks, make sure they are clean and dry then apply a 3-5mm bead of silicone sealant as shown in Fig.9. Keep the bead close to the inside edge. This prevents it from appearing on the exterior when you press the panel into place.

Do not put any silicone on the centre piece at the back of the subwoofer bricks; otherwise, sound cannot travel from the driver to the port! However, you do need to seal the centre section at the front so as to direct all the sound to the back and then around to the port.

Use an adhesive type silicone. We used one called Parfix Kitchen & Bathroom Silicone Sealant, again purchased at the local Bunnings.

Take your prepared rear timber panel and gently lay it on the silicone bead. Once you are happy with its position, slowly press it down onto the brick. If any silicone squirts out the edges, quickly wipe it away with a damp cloth. Add weight on top (eg, a pile of books) to keep the panel in position and leave it to cure for at least 24 hours. Make

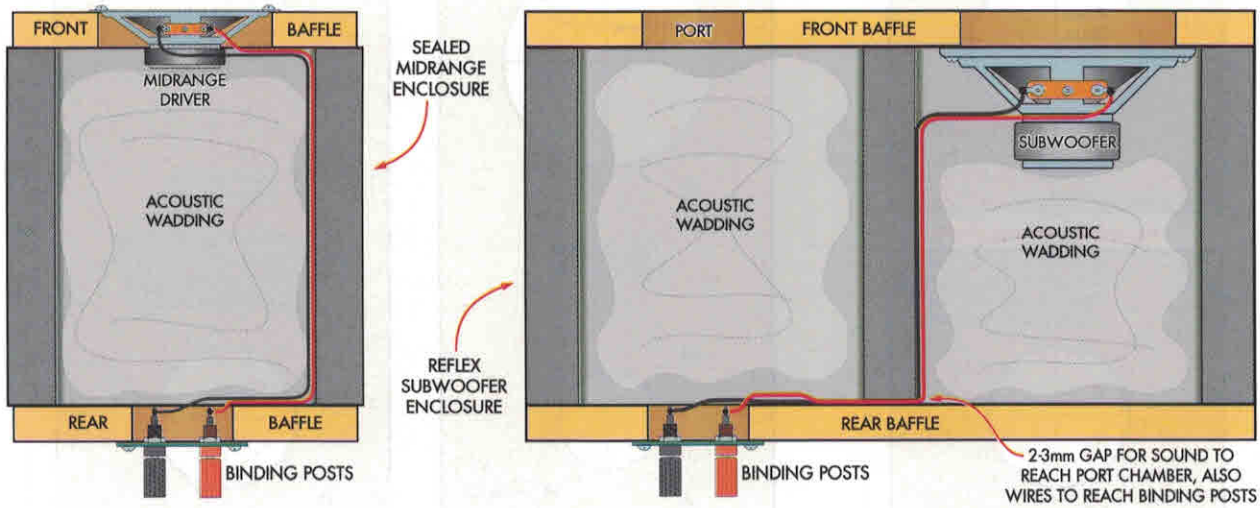


Fig.6 (left): the sealed midrange enclosure is made from a "half block" and midrange driver as this semi-section shows.
Fig.7 (right): the ported subwoofer is made from a "full block" and subwoofer driver with a tiny air gap between the halves.

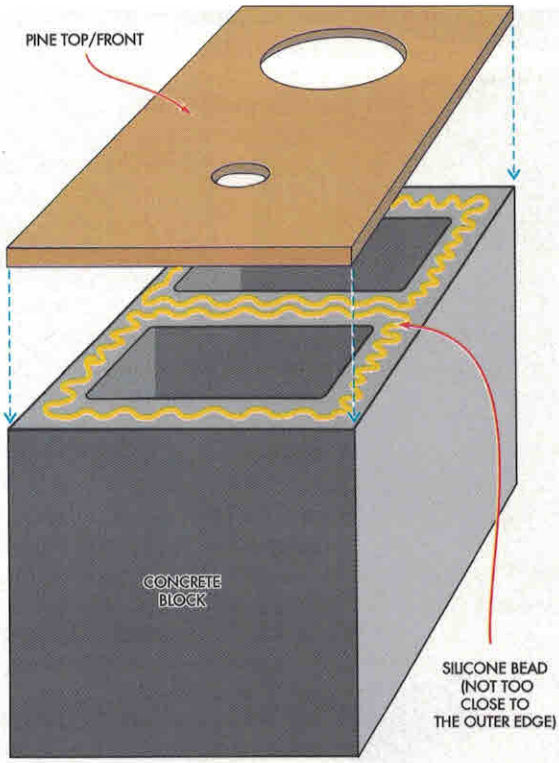
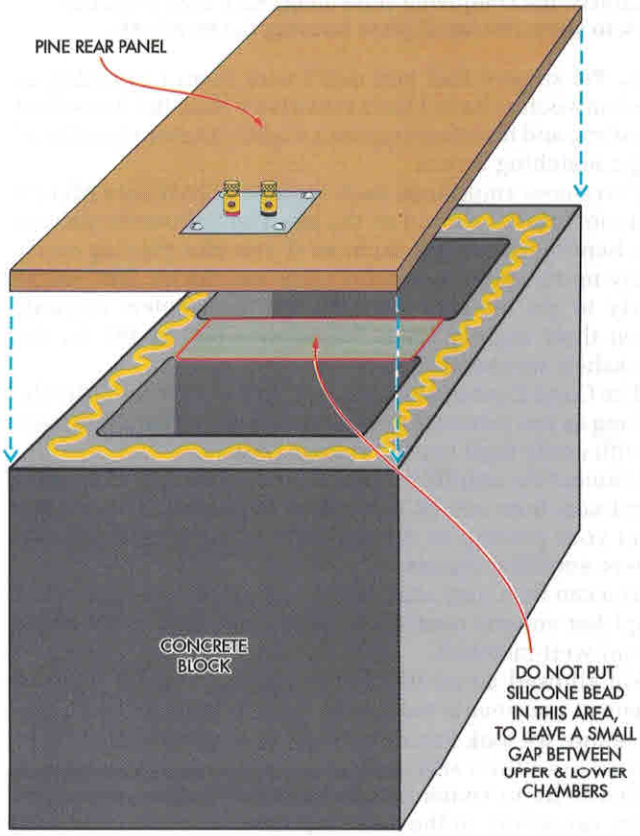


Fig.8 (above): front side view showing how the "baffle" is secured to the concrete block. Make sure you use plenty of silicone so the join between the block and panel is airtight .

Fig.9 (below): similarly, here's how the rear panel is attached to the block. Make sure air can flow between the two block halves, as explained in the text .



sure its position is correct because once it cures, you will not be able to shift it!

Repeat this procedure with all the other enclosures.

After 24 hours (or more, if you are in a cold climate), repeat this procedure with the front baffles (see Fig.8). Just remember to add the silicone across the centre of the subwoofers this time.

After another 24 hours, you are ready to mount the drivers. But first, cut 60-70cm lengths of speaker wire and solder them to each driver.

When the silicone on the cabinets is completely cured, pack the subwoofers with acoustic wadding. We used Acousta-Stuf Polyfill, from Parts Express; see: **http://siliconchip.com.au/link/aayq** It is also available from Jaycar.

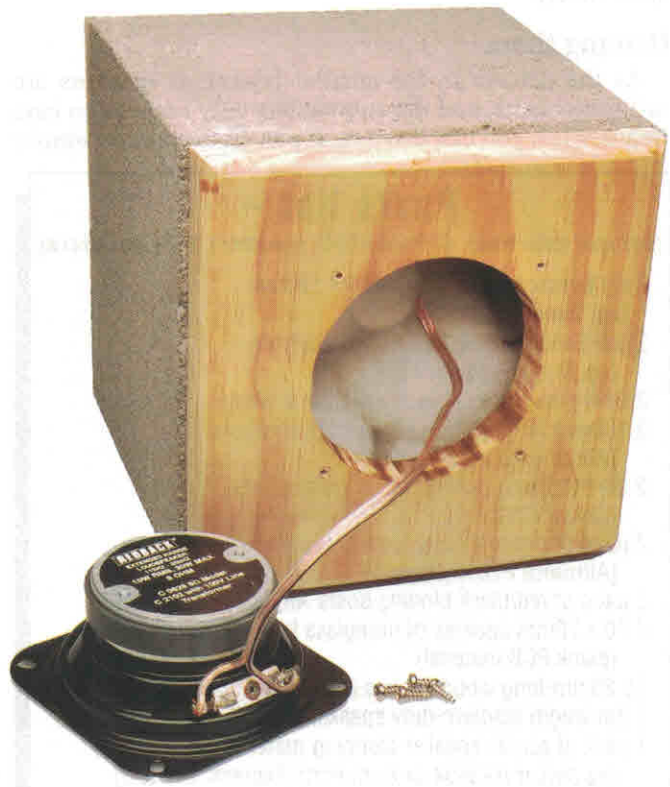
Pack this in loosely behind the drivers. In a pinch, you can also use small (dry) towels.

Push the speaker wires through so that they are sticking out the hole in the back panel, then mount the drivers using wood screws. You'll get the neatest result if you first mark and drill small pilot holes, using the driver surrounds as templates. Try to orientate the drivers all the same way; it generally looks best to have the screws in the diagonal corners, as shown in our photos.

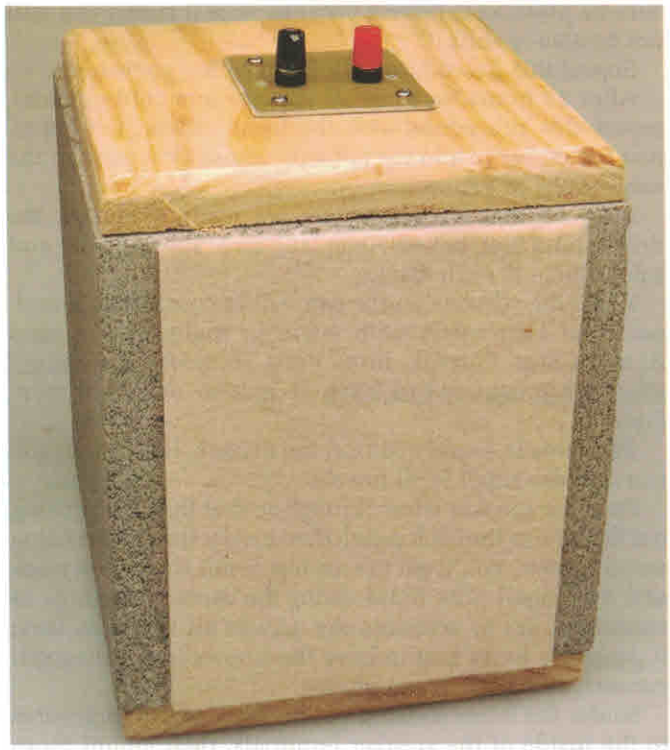
Solder the wires sticking out the back of the enclosures to the inside of the speaker terminals, then mount those terminals on the rear panels in a similar manner. Your speakers are finished!

Note that you can stack the smaller speakers on top of the subwoofers, or you can locate them separately. The placement of the subwoofers is not critical.

Depending on the surface your speakers are going to be



Front view showing the baffle secured to the half block and the acoustic wadding inside. The four screwheads could be painted black so they don't stand out as much.



The finished midrange speaker, here shown from the under-side, with a 170 x 170mm piece of thin felt glued to the block to ensure it doesn't scratch underneath surfaces.

placed on, you might like to glue a 190 x 190mm square of felt or similar protective material on the underside of each of the blocks. Concrete scratches most other surfaces quite nicely!

Driving them

As the drivers in the smaller bookshelf speakers are full-range units, and the subwoofers only respond to bass frequencies, you can drive each pair from separate amplifiers. We suggest that you don't wire them in parallel as the Subwoofers have lower sensitivity than the Bookshelf speakers, and therefore require a slightly higher signal level to get matching levels.

Two stereo amplifiers, each capable of 25W into 8Ω or a bit more into 6Ω should do the job. The Subwoofer drivers can handle up to 50W each, so if you like playing really bassy music, more powerful amps are the go. But you're likely to get more power into the Subwoofers anyway, given their slightly lower impedance (6Ω vs 8Ω for the Bookshelf speakers).

The Class-D modules we mentioned earlier are suitable, as long as you power the ones driving the subwoofers from a sufficiently high supply voltage (20V+).

Connect the amplifier outputs to the four sets of speaker terminals, then use RCA Y-cables to connect the outputs from your preamp to the left/left and right/right pairs of power amplifier inputs.

You can then play some music and adjust the individual amplifier volume controls until the bass and treble levels sound well-matched.

We allowed about two hours playing various types of music at reasonable volume to "run in" the speaker drivers before we took measurements; you may find that these drivers are a little stiff straight out of the box. You should notice an improvement in the sound with time, as you use them, especially in the bass response. SC

Similarly, the completed subwoofer, here seen from the back to show the small plate housing the terminals.

Parts list –

(for one pair each of Bookshelf speakers & Subwoofers)

- 2 full Besser blocks, 390 x 190 x 190mm [eg, Bunnings 3450457]
- 2 half Besser block, 190 x 190 x 190mm [eg, Bunnings 3450458]
- 2 DAR pine planks, 184mm x 1.8m x 19mm
- 2 100mm (4in) 15W 8Ω twin cone speakers [Altronics C0626]
- 2 5in (125mm) woofer/midrange speakers [Jaycar CW2192]
- 2 pairs of pre-mounted speaker terminals [Altronics P2017, Jaycar PT3012] ***OR***
- 2 pairs of red/black binding posts ***AND***
- 2 70 x 70mm squares of fibreglass laminate (blank PCB material)
- 16 20mm-long wood screws (eg, No.9/4.5mm thread)
- 1 3m length medium-duty speaker cable (figure-8)
- 1 pack of acrylic speaker damping material [eg Jaycar AX3694 or from Parts Express; see text]
- 4 squares protective felt (or similar), ~170mm x 170mm
- 1 tube of neutral-cure clear silicone sealant

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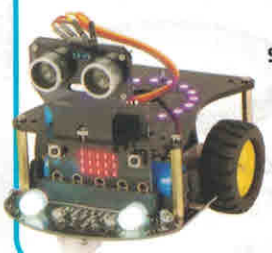

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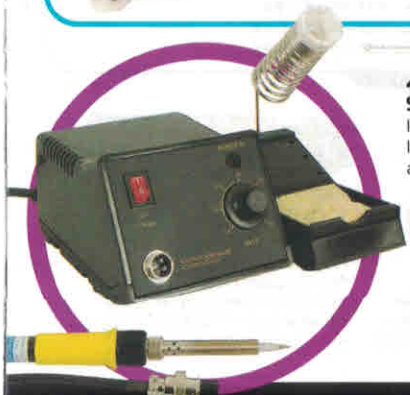

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ONLY **$16.95** EA

200GM DURATECH SOLDER
60% Tin / 40% Lead. Resin cored. 2 sizes available.
1.00mm NS3010
0.71mm NS3005

JUST **$16.95**

SOLDER SUCKER
Constant vacuum force maintained throughout and automatically cleans itself with each action. 195mm long.
TH1862

YOUR DESTINATION FOR POWERING YOUR PROJECTS

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Laboratory Power Supplies

Our range of highly efficient and reliable benchtop power supplies are specially selected to suit your unique testing and servicing applications. They use proven technology and are designed to give long service life in workshop situations. Features include low noise, low ripple and protection against overload and short circuit. Available in fixed or variable voltages. The most cost effective solution for your laboratory use, electronic and communications equipment maintenance.

MP3800 JUST $159

MP3800

MP3079 (Shown) JUST $79.95

MP3089 JUST $219

MP3079

MP3840 ONLY $189

MP3840

	MP3079 & MP3089	MP3800	MP3840
Features	Fixed output voltage, also available in 20A & 40A models	Compact size, high current and variable output.	Digital control & a large easy to read LED display. Over-current & short circuit protection are built-in.
Output Voltage	13.8VDC	0-24VDC	0-30VDC
Output Current	12A	17A	5A
Display	-	Analogue Meter (backlit) screen	LED screen
Size (W) X (D) X (H)	170 x 160 x 85mm	148 x 162 x 62mm	110 x 156 x 260mm

HIGH POWER MAINS POWER SUPPLIES

Slim mains power adaptors designed with low energy consumption. Regulated output voltage. Fits side by side on a power board. Supplied with 7 changeable DC tips.

12VDC 4A 48W MP3550 **$39.95**
12VDC 5A 65W MP3560 **$49.95**
24VDC 2.5A 65W MP3562 **$49.95**
48VDC 1.25A 65W MP3564 **$49.95**

- **HIGH POWER**
- **SLIM & LIGHTWEIGHT**

FROM $39.95

MP3550

ONLY $59.95

65W UNIVERSAL LAPTOP POWER SUPPLY WITH USB SOCKET

Compact size, high power plug pack design. Automatic voltage detect. Compatible with popular laptops from HP, Dell, Toshiba, IBM, Lenovo etc. MP3342

VARIABLE LABORATORY AUTOTRANSFOMER (VARIAC)

- Heavy-duty steel housing case
- 500 VA (fused) rated power handling
- 0~260 VAC @ 50Hz output voltage
- 165(D) x 120(W) x 160(H)mm

MP3080

ONLY $199

FROM $19.95

MP3295

ENCLOSED POWER SUPPLIES

A range of mini enclosed switchmode power supplies with single (RS) or dual (RD) outputs.

15W 5V MP3295 **$19.95**
15W 12V MP3296 **$19.95**
25W 12V MP3297 **$23.95**
25W 24V MP3298 **$23.95**
65W 5V/12V MP3299 **$49.95**

ISOLATED STEPDOWN TRANSFORMERS

Fully-enclosed with fold up metal carry handles. Approved 3-wire power cord & US style 2 pin 110 - 115V socket.

120W MF1080* **$119** (Shown)
250W MF1082 **$169**
500W MF1084 **$289**
1000W MF1086* **$399**
*In-store only. Limited stock.

FROM $119

MF1080

72VA EI CORE TRANSFORMER

24V 72VA 3A single winding type 2158 with 200mm flylead connection. MM2012

ONLY $29.95

20VA TOROIDAL TRANSFORMERS

High efficiency, small size and low electrically induced noise. Single bolt mounting.

9V+9V MT2082
12V+12V MT2084
15V+15V MT2086

JUST $29.95 EA

Automotive Power

"CONDURA" STYLE DC ROCKER SWITCHES

All switches come with double-LED illumination, a standard rocker cover and a standard range of decals to customise the switch to your application.
Rated 20A @12V, 10A @24V
See website for compatible laser-etched covers.

White SK0910
Red SK0912 (Shown)
Blue SK0914
Orange SK0916

JUST $15.95 EA

SK0912

2-PORT PANEL MOUNT USB CHARGER

Designed for charging your electrical devices. Comes complete with a protective cap with short-circuit protection. Easy installation.

- Input: 12-24VDC
- Dual USB outputs: 5VDC, 3.1A (shared)

MP3618

JUST $24.95

SZ2031

SZ2032

FROM $29.95

FUSE BLOCKS WITH BUS BARS

Accepts up to 30A per output with handy fuse-blown indication. Negative bus bar.

6-Way SZ2031 **$29.95**
12-Way SZ2032 **$39.95**

ONLY $26.95

AUTOMOTIVE FUSE PACK

Kit contains around 120 standard size automotive fuses housed in a 6 compartment storage box. 20 x 5A, 10A, 15A, 20A, 25A & 30A fuses included.
SF2142

YOUR DESTINATION FOR SIGHT & SOUND PROJECTS

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FROM **$24.95**

Build your own speaker

FROM **$1.95**

POLYSWITCHES PTC FUSES - SPEAKER PROTECTION

Low cost speaker protection against electrical (current) overload in most situations. Other values available.
RXE075 60V RN3460 **$1.95**
RXE250 50V RN3470 **$2.95**
See online for trip ratings.

JUST **$12.95**

2-WAY GOLD TERMINALS ON A PLATE

Top quality speaker terminal.
- Plate size 99 x 99mm.
- Hole cutout is round - 78mm dia.

PT3012

GOLD PLATED BANANA PLUGS

Designed for monster type speaker cable. Side entry hole, with finger screw locking action.
Red PP0426
Black PP0427

JUST **$4.95 EA**

FROM **$14.95**

30M ROLL SPEAKER CABLES

Light Duty 14/0.14mm	WB1703 **$14.95**
Heavy Duty 24/20mm	WB1709 **$35.95**
Extra Heavy Duty 79/0.2mm	WB1713 **$89.95**

RESPONSE

PAPER CONE WOOFERS

Excellent for replacement or for new speaker design construction. Produces clean bass output for any musical application. Equipped with strong steel frame baskets, high power magnet and voice coils.

4" 27WRMS	CW2190 **$24.95**	**8" 90WRMS**	CW2196 **$39.95**
5" 50WRMS	CW2192 **$29.95**	**10" 225WRMS**	CW2198 **$69.95**
6.5" 60WRMS	CW2194 **$34.95**	**12" 225WRMS**	CW2199 **$89.95**

ONLY **$19.95**

3" 15WRMS FULL RANGE SPEAKER

Suitable for use in home theatre, surround speakers, multimedia speakers and portable speakers. 8-Ohm. AS3034

JUST **$19.95**

25MM TITANIUM DOME TWEETER

Produces very crisp and clear high frequencies. 50WRMS. 8-Ohms.
CT2007

Improve your TV's Reception!

INDOOR SPLITTER - 2 WAY

Connect two TV, video, games, FM receivers etc to one RF plug to run multiple devices on one outlet.
LT3020

JUST **$5.95**

KINGRAY FOXTEL® APPROVED SPLITTERS

Excellent RF screening to reduce interference.
- 1 x F-type input to 2 or 4 F-type outputs

2-Way LT3069 **$7.95** (Shown)
4-Way LT3071 **$12.95**

FROM **$7.95**

KINGRAY AMPLIFIER MASTHEAD 35DB

Provides a good VHF & UHF TV band gain, and user selectable filters for VHF bands 1&2, FM radio, fixed pagers, and the new 4G/LTE band.
LT3251

JUST **$119**

43 ELEMENT UHF TV ANTENNA

Ideal for metro/medium signal reception areas.
- Built-in filter for 4G/LTE network signals
- 13dB gain, 21-52 channels, 4-5 bands and 470MHz to 862MHz frequency

LT3181

JUST **$49.95**

SINGLE POWER PASS SPLITTERS

These have power pass on the input to one output. These allow the voltage on one port only, so if anything goes wrong, all parts are not affected by low frequency shorts. Supplied with mounting screws.
2-Way LT3046 **$12.95** (Shown)
4-Way LT3047 **$17.95**

FROM **$12.95**

2-WAY INDOOR AMPLIFIER/SPLITTER

Split and amplify your UHF, VHF or FM signals. Features high gain and low noise to ensure your signal is of a high quality. Wall mounted for greater convenience.
- 2 x 87dBuV max. output

LT3282

JUST **$29.95**

INDOOR TV AMPLIFIER/ SPLITTERS

A neat solution to boost your TV antenna signals.
Single LT3285 **$44.95** (Shown)
4-Way LT3287 **$89.95**

FROM **$44.95**

DIGITAL TV SIGNAL STRENGTH METER

Easy to read pocket sized DVB-T meter. Correctly adjust the angle of your digital TV antenna. Adaptors included.
- Requires 1 x 9V battery (SB2423 **$4.50** sold separately)
- 40-862MHz frequency range

LT3332

JUST **$39.95**

ROTARY COAX STRIPPER

Strips the outside jacket and inner conductor in one operation. Simply rotate clockwise around the cable 3 to 6 times.
- Suitable for RG58/59/62/6 and 3C2V 75 ohm cable

TH1820

JUST **$19.95**

HEX RATCHET CRIMPING TOOL

Crimps F, N, BNC, TNC, UHF, ST, SC & SMA connectors onto RG6 or RG58 coax cable. Four hex crimping dies: 1.72mm, 5.49mm, 8.23mm and 9.14mm.
TH1833

JUST **$39.95**

TV COAX CABLE

Great for domestic TV & Pay TV installations! 75 ohm RG6 quad shield in a handy 30m roll. WB2014

JUST **$49.95**

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RASPBERRY PI 3B+

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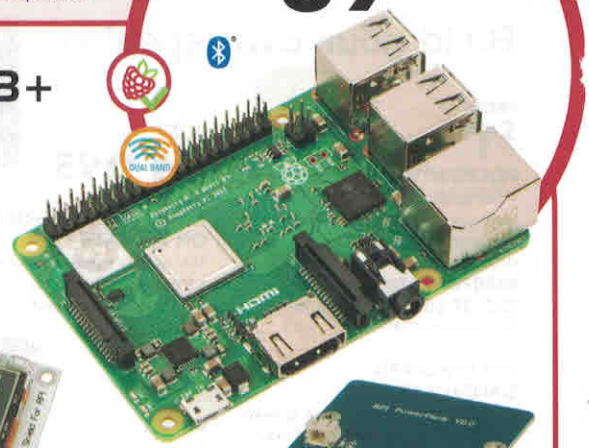

Tiny credit card size computer.
- 1.4GHz 64-bit quad-core processor
- Dual Band 2.4GHz & 5GHz Wireless LAN
- Bluetooth® 4.2 technology with BLE
- Faster processing and networking
- Supports Power-over-Ethernet (with separate PoE HAT)

XC9001

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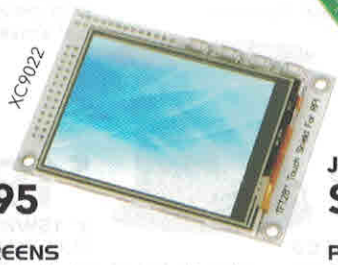
OFFICIAL RASPBERRY PI 3B CASE
Snap-together case with numerous removable panels. Stylish red and white design. Easy no-tools assembly. Four Rubber feet included. XC9006

JUST **$24.95**

5MP CAMERA
Connects directly to the camera connector on the Raspberry Pi. Supports up to 1080p video, up to 2592x1944 pixel images. XC9020

ALSO AVAILABLE:
5MP NIGHT VISION CAMERA XC9021 **$49.95**



FROM **$29.95**

TOUCH SCREENS
Compact, portable display to connect directly to your Pi. HDMI input and includes a resistive touch interface.

2.8" 320x240 Resolution XC9022 **$29.95**
5" 800x480 Resolution XC9024 **$99.95**
7" 1024x600 Resolution XC9026 **$159**

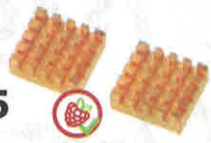
JUST **$29.95**

POWER PACK
Portable power expansion board with Li-ion battery pack.
- Attaches Directly to Raspberry Pi
- 2 USB Output Ports

XC9060

3.7V 3800mAh Li-Ion Battery included

COPPER HEATSINK - 2 PACK
This two pack of heatsinks allows you to fit one to the CPU and one to the GPU on your Pi. Can even be used on motor driver ICs or other power ICs and regulators.
HH8584



JUST **$7.95**

RETRO NES STYLE CONTROLLER
SNES layout. Features A/B/X/Y buttons, start, select, and direction controls. Easily configurable, USB powered. XC4404

JUST **$9.95**

GPIO EXPANSION KIT
Colour coded rainbow ribbon cable, all 40 GPIO pins are broken out to a header which can be plugged straight into a breadboard. Clearly labelled header.
XC9042

JUST **$12.95**

POWER SUPPLY FOR RASPBERRY PI
5.1V 2.5A. Use with Raspberry Pi 3/3B+, charge power banks, etc. 1.5m lead with micro USB connector. MP3536

JUST **$23.95**

PCB MOUNT SCREW TERMINALS - 5MM
Ideal for those situations where wires leave a PCB.
2-Way 8A HM3172 **$1.35**
3-Way 8A HM3173 **$1.75**

FROM **$1.35**

IP65 SEALED ENCLOSURES
Designed to IP65 of IEC529 and NEMS 4. Moulded in dark grey.
- Lid fixing screws are M-4 stainless steel (non-magnetic) into threaded brass inserts
- Some sizes available with flange mount HB6120-HB6134

See website for full range.

PUSH BUTTON SWITCHES
IP67 rated for harsh environments, low profile dome shape, momentary action.
Black Button SP0656
Red Button SP0657

FROM **$6.95**

JUST **$4.95 EA**

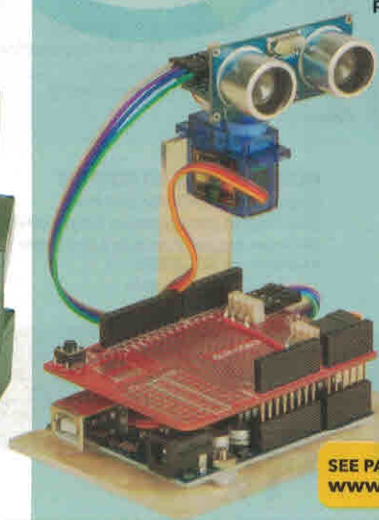
DIECAST HEATSINK
No flange. Thermal resistance 0.72°C/W.
150(L) x 75(H) x 46(D)mm
HH8555
See in-store or online for full range

JUST **$22.95**

PROJECT: ULTRASONIC RADAR

Watch a cool radar slide across your computer screen like the old war-time movies! Using the simple ultrasonic sensor to measure distance in a rotating fashion across your workbench. Uses Arduino and the easy-to-use "Processing" for GUI programming on your computer.
Note: Accuracy of detecting helicopters not guaranteed.

SKILL LEVEL: Begginner
TOOLS: Drill, Soldering Iron



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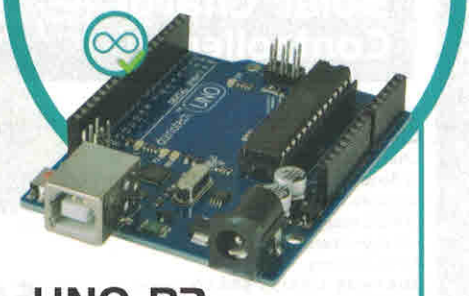
DUAL ULTRASONIC SENSOR MODULE.
The popular HC-SR04 ultrasonic distance module provides an easy way for your DuinoTECH to measure distances up to 4.5m. Uses two digital pins.
- 45(W) x 20(D) x 13(H)mm

XC4442
JUST $7.95

TEMPERATURE AND HUMIDITY SENSOR MODULE
Measure both temperature and humidity. Features resistive-type humidity measurement.
- 0 °C - 50 °C +/- 2 °C range
- 20 - 80% +/- 5% humidity
- 1Hz sample rate

XC4520
JUST $9.95



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RED LASER DIODE MODULE
Need a red laser light for your latest project? Here it is! Everything you need to drive the laser diode is included on the board. Just connect it to 5VDC and you're good to go! XC4490
JUST $4.95

240 x 320 LCD TOUCH SCREEN
Large, colourful touch display shield which piggybacks straight onto your UNO or MEGA.
- Fast Parallel interface
- Micro SD Card slot
- Resistive touch interface

XC4630
JUST $29.95

UNO R3 DEVELOPMENT BOARD
100% Arduino® compatible. Stackable design makes adding expansion shields at ease. Powered from 7-12VDC or from your computers USB port. ATMega16u2 USB-Serial chipset. XC4410

Motor & Power Control for your Project

FROM $5.45

RELAY MODULES
Use your DuinoTECH to switch real world devices up to 10A per channel. Includes back-EMF protection and LEDs.
1 Channel 5VDC XC4419 **$5.45**
4 Channel 12VDC XC4440 **$12.95**

JUST $7.95

24V 5A MOS DRIVER MODULE
Accepts Pulse Width Modulated (PWM) input to drive 24VDC loads. Perfect for many projects such as lighting, DC motors, pumps and solenoid.
- Output current 5A

XC4488

JUST $7.95

DC VOLTAGE REGULATOR MODULE
Accepts any voltage from 4.5- 35VDC, and outputs any higher voltage from 3-34VDC. Output voltage is adjusted via a multi-turn potentiometer.
- Max output current 2.5A

XC4514

JUST $9.95

5V STEPPER MOTOR WITH CONTROLLER
A small, versatile motor and driver set that can be used with any Arduino® compatible boards via jumper leads.
- Four-phase LED indicates the status of the stepper motor

XC4458

JUST $11.95

30A CURRENT SENSOR MODULE
Outputs a voltage proportional to current passing through the sense pins on the module.
- Output ratio is 66mV/A
- On-board power indicator

XC4610

JUST $12.95

MOTOR SERVO CONTROLLER MODULE
Capable of driving up to 4 bi-directional DC motors or 2 stepper motors.
- 5V to 16VDC

XC4472

JUST $14.95

STEPPER MOTOR CONTROLLER MODULE
Allows full control of two DC Motors or one stepper-motor. On-board 5V regulator.
- Motor voltage: 3-30VDC
- Requires six digital inputs

XC4492

JUST $19.95

DC-DC BOOST MODULE WITH DISPLAY
Provide higher voltages for your project.
- Maximum 2A input current without heatsinking
- Output from 5V-35V

XC4609

FROM $4.95

BREADBOARD LAYOUT PROTOTYPING BOARDS
A prototyping board that lets you transfer your breadboard design without having to rework it. Includes five holes on each side per row and power rails running the length of the board.
Small 400 Hole HP9570 **$4.95** (Shown)
Large 862 Hole HP9572 **$9.95**

JUST $14.95

BREADBOARD WITH 830 TIE POINTS
With labeled rows and columns and adhesive back for mounting, it is ideal for electronic prototyping and Arduino projects.
- 200 distribution holes
- 630 terminal holes

PB8815

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RGB LED STRIP MODULE
Strip of eight RGB LEDs which can be controlled by a single Arduino pin. Up to 1000 LEDs can be daisy chained and run from one pin.
- Each channel has 256 brightness levels
- Current draw 500mA per module maximum

XC4380

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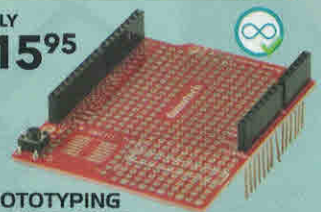


PROTOTYPING BOARD SHIELD
This stackable shield makes semi-permanent prototyping simple. When you want something more permanent than a breadboard, but don't want to make your own PCB, this shield is the answer.
XC4482

What's NEW

Tech Talk: Solar Charge Controllers:

PWM: Pulse width modulated controllers continually apply voltage pulses to the battery whenever the panel is providing sufficient voltage.

MPPT: Maximum power point tracking controllers maximise power conversion between the panel output and the battery input by using a DC to DC switchmode power converter.

12V/24V 30A SOLAR CHARGE CONTROLLERS

Charges 12V or 24V lead acid (sealed, gel, or flooded) or 12V lithium battery banks and supports 12V solar arrays up to 500W or 24VDC arrays up to 1000W.

- 3-stage charging
- 2 x USB Ports

30A PWM MP3755 **$89.95** (Shown)
30A MPPT MP3743 **$249**
50A MPPT MP3745 **$349** (Shown)

FROM **$89.95**

DUAL INPUT DC/DC MULTI-STAGE BATTERY CHARGER

Designed to manage solar and alternator power inputs to charge an auxiliary (house) battery system. Dual input: solar and/or alternator/car battery. 20A max charging current (automatically controlled). Six-stage battery charging. Supports Lead acid, AGM, Calcium, GEL or LiFePO4 batteries.
MB3940

JUST **$219**

7-STEP INTELLIGENT LEAD ACID AND LITHIUM BATTERY CHARGER

Charge your batteries and recover slightly sulfated batteries to increase battery life. Suitable for 6V or 12V Lead Acid batteries between 1.2Ah - 26Ah, or 12.8V LiFePO4 from 2Ah to 15Ah.

- Supports Sealed, Gel, AGM or Flooded Lead, and LiFePO4
- IP65 weatherproof rated
- Short circuit, overload and reverse polarity protection

MB3902

JUST **$29.95**

NEXTECH

- AUTOMATIC CONNECTION DETECTION
- PLUG AND PLAY

FROM **$39.95**

ETHERNET SWITCHES

Ultra-fast Ethernet connectivity with gigabit speeds. Provide additional ports to an internet router, firewall, or a standalone network.

- Backward compatible with 10/100 interfaces
- 10/100/1000Mbps RJ45 Port
- Automatic connection detection

5 Port YN8395 **$39.95** (Shown)
8 Port YN8397 **$59.95**

NON-CONTACT INFRARED THERMOMETER

Get fast and accurate readouts via the infrared sensor without needing to come in contact with the temperature source.

- 0°C - 118°C temperature range
- 5cm-10cm measuring distance
- +/- 0.2°C accuracy

QM7422
Note: Delivery charges may apply.

JUST **$199**

- 130° 1080P RESOLUTION
- MOTION DETECTION
- IP65 HOUSING

SMART WI-FI BATTERY CAMERA

For around the home or workplace, without the need for messy cables! Allows viewing from anywhere in the world via Smart phone app.

- Rechargeable
- Infrared LEDs for night vision

QC3890

ALSO AVAILABLE:
Solar Panel to suit
QC3896 **$59.95**

JUST **$199**

720P MOTION WI-FI CAMERA WITH FLOOD LIGHTS

All-in-one security camera designed to be mounted outdoors to deter or record any intruders.

- Solar powered
- Internal memory
- Wi-Fi capable

QC8047

- 2x 3W LEDS
- WIDE-ANGLE LENS
- MICROSD CARD RECORDING

JUST **$229**

JUST **$29.95**

DOOR OR GATE ALARM

Be alerted when someone opens a gate or external door at your premises.

- Chime or 100dB siren
- Panic mode
- Waterproof

LA5208

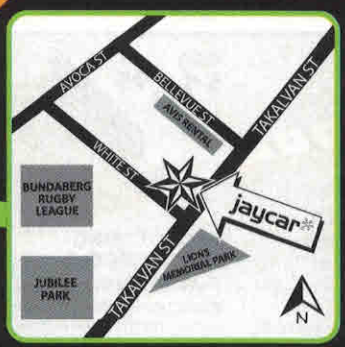
JUST **$16.95**

WIRELESS DOORBELL WITH 38 MELODIES

Battery operated wireless doorbell that can be installed in minutes.

- 38 Selectable melodies
- Adjustable volume
- Up to 80m range

LA5054



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SERVICEMAN'S LOG

Treadmill trials over trails

Dave Thompson

Being stuck inside for a long time, we've found that we (try to) use things that haven't been touched in a while. Some of them have been sitting around for so long that they no longer work properly. In the case of our treadmill, the repair job provided more exercise than actually using it!

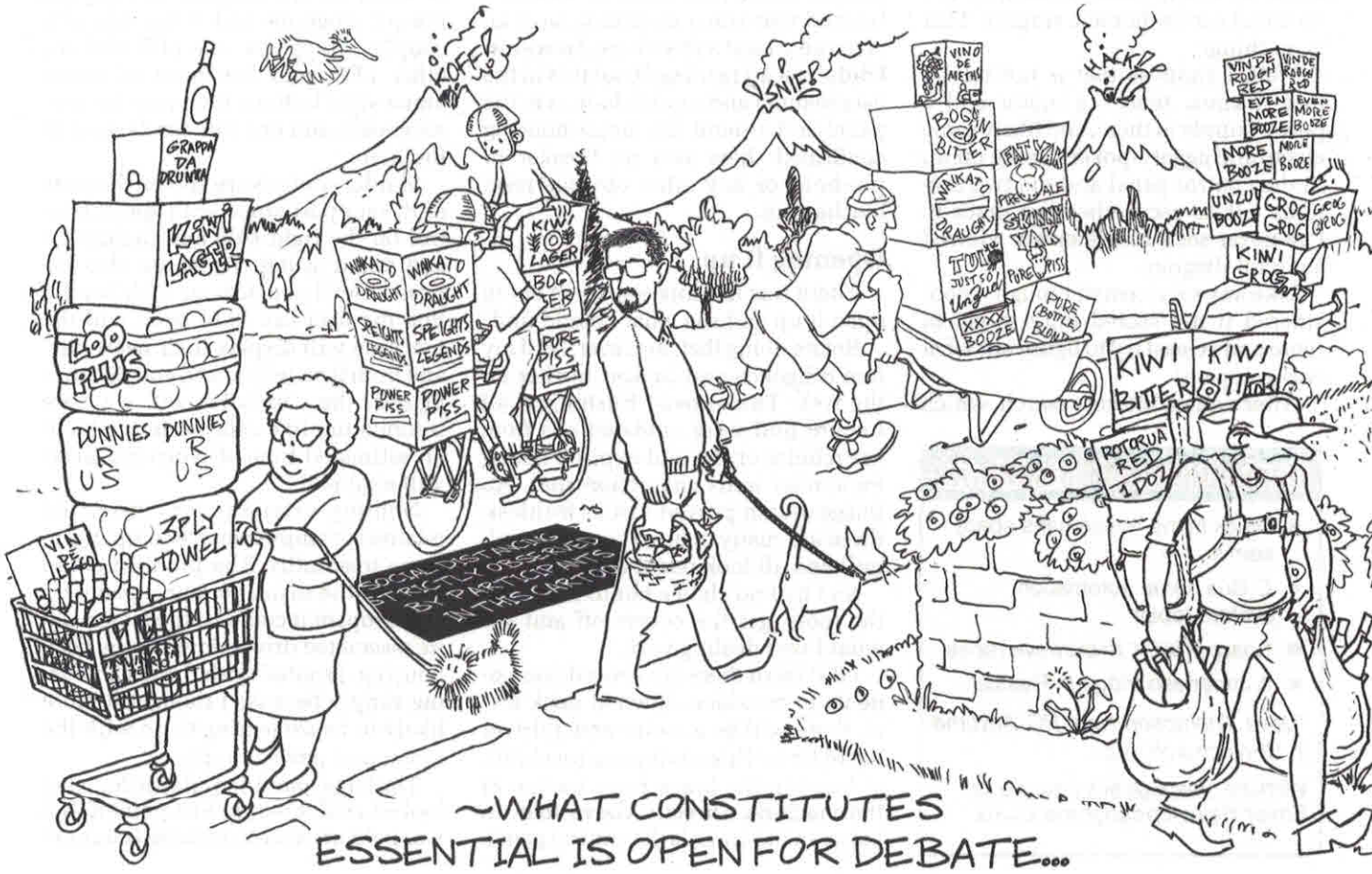
At the moment, I'm only allowed to go out of my house to shop for essential supplies (though what constitutes essential is open for debate) or to walk or cycle for exercise. I have to say I've never seen so many people out and about; like us, they probably want to get out of the house to stave off 'cabin fever'. It is sometimes so busy on the footpaths it is challenging to maintain the required 2m separation!

Combine this with increasingly-grubby autumnal weather and walking has become a lot less appealing. Luckily, a few years ago we invested in a good quality treadmill. However, like the vast majority of exercise equipment, after six months of solid use, we used it less frequently, and it now sits in the spare room gathering dust.

To be fair, the treadmill isn't totally unused; the wife uses the arms to hang washing on, and we store boxes of who-knows-what on the mat! Given the current situation, though, it seemed prudent to press it back into service.

After a good clean, it looked brand new, even though it is going on for 10 years old. That's the great thing about equipment that typically doesn't get much use. At least it stays in good condition! That said, we did do many kilometres on this one back in the day, though my motivation was more wanting to get my money's worth out of it rather than personal fitness!

This model is marketed under the name ProRunner; a brand likely dreamt up by the big-box company that sells these treadmills. It wasn't inexpensive and is very well made, rock-solid and almost to the level of what you'd find in a fitness centre. It has done everything we'd asked of it,



so I considered it money well spent at the time.

The treadmill stops running

To prep it for use, I vacuumed all the dust off the frame and control panel and wiped down the belt surface. I also broke out the long-necked squeeze-bottle of silicone spray grease that came with the machine and as per the user manual, lubricated the deck and the underside of the mat.

So far, so good; the machine was running as smoothly as ever, and the wife and I had several sessions over the following days. Then, a few days ago, as the wife was finishing her program and was in the cool-down phase, it shut down unexpectedly. The control panel flashed on and off about once a second, and each time it went dark, a beep sounded from the built-in piezo buzzer.

Thinking it had simply 'crashed', she hopped off and turned the main switch off and on a few times, hoping this would reset it. There was no change; all she got from it was the rhythmic buzzing and blinking.

She called me in, but there was little I could do. Full disclosure: I know as much about treadmills as I do about cardiothoracic surgery. That is, nothing.

Well, I suppose that is not totally true; I know there's a motor and a power supply in there, and likely some electronic jiggery-pokery going on up in the control panel and the two sections talk to each other, but that's it. I've never seen inside one or viewed a circuit diagram.

Like any serviceman though, I considered it my sacred duty to get in there and at least try to figure out what was going on!

After a quick internet search, which revealed little-to-no technical information about this make or model, I learned that some machines have an electronic reset somewhere. However, I didn't recall reading about this in the user manual and a quick look over the panel and around the motor housing confirmed there was no breaker or pin-hole, or any other obvious reset mechanism.

Opening it up

There was nothing else for it but to open it up and see what I could find.

Before doing that, however, I did my due diligence and looked further on the web. This proved frustrating; all I could find were outdated ads from the retailer or the odd expired listing for similar units on auction sites. An image search proved just as fruitless; there are many, many types of treadmill and all look much the same.

So I had no choice but to break out the tools, get the covers off and see what I was dealing with.

I did learn there are several components to consider; down at deck level, there will be a motor and a driver board for it. This sits (on our treadmill, at least) in the lower front section of the machine. Directly above that, in between the arms, is the control panel.

This is the part we mindlessly look at when we are slogging through the pre-set programs and it consists of a couple of displays, one LCD and another LED, and few rows of membrane-style buttons (one row for pre-set speeds and one row for degrees of incline).

Similar controls are also on the ends of the support arms, with speed control on the right side and incline up and down at left. There are also exposed metal contacts on each handle that the user can hold onto, and the machine will display their heart rate, and from that, with speed and distance figures, the controller will estimate information like calories burned and an estimated time of when my heart will explode!

Nothing extraordinary there, but relatively comprehensive compared to some treadmills. The problem could lie with the display/control panel up at the top, or it could be the motor and its associated driver down in the deck housing. I started with the deck housing simply because I thought it more likely to be something to do with the motor and power supply.

The large, moulded-plastic housing looked as if it would just pop off, but was held up with something I couldn't

Items Covered This Month

- Stuck in the house sans spare semis
- C-Bus home automation system repair
- Sharp R350Y microwave repair
- A Japanese fridge in Russia

*Dave Thompson runs PC Anytime in Christchurch, NZ.

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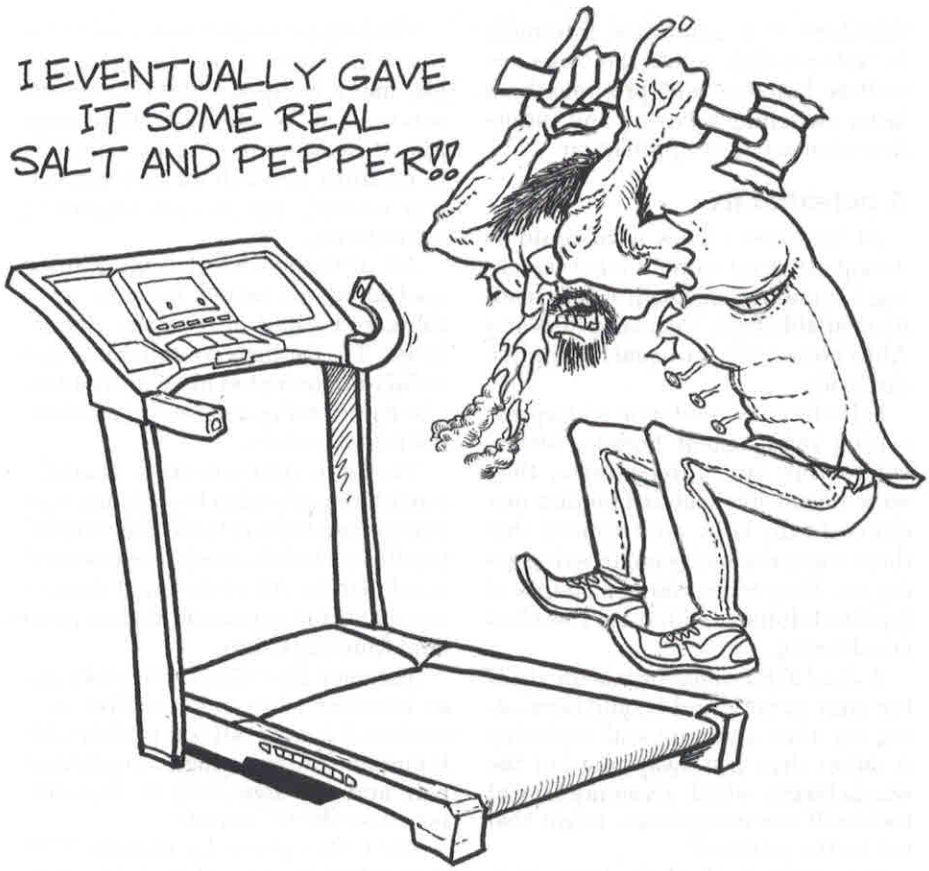


see. I could move the housing a little, and unclipped it from two locations in the very front, but something was holding it together further back. I couldn't see any screw holes, and went so far as to lift the machine up so I could check underneath for fasteners, but nothing was visible.

A viscous problem

I assumed it to be just strong clips holding it together, so I worked my fingertips in the gaps between the housings and applied increasing pressure, expecting it to let go, but it stubbornly refused to give. What a great start to my treadmill adventure. I couldn't even figure out how to get it open!

After much huffing and puffing and purple language, I eventually gave it some real salt and pepper, and it started letting go. One by one, six turret clips finally popped loose. When I manoeuvred the housing away from the deck, I could see what had been holding it up: glue. Big, opaque blobs of glue.

Great, it was going to be one of those jobs. Someone, somewhere, must have thought that clips alone just aren't good enough for our treadmills, let's smother everything with glue and make it almost impossible to service!

A quick look around the motor bay proved my hypothesis; anything exposed or connected was slathered with a generous dollop of the stuff. And it isn't like hot-melt glues and silicones I've encountered before; in some places, it is very hard and brittle and breaks away, while in other areas it rolls and stretches, making it very difficult to remove.

I was loath to get my heat gun anywhere too close in case I damaged any of the other parts, many of which are plastic, so when I had to remove glue from anything, I resorted to picking away at it with my fingers.

I had to admire the motor and controller assembly. The DC motor might be long and relatively small in diameter, but it is exceedingly torquey. One end of the armature drives the mat via a toothed belt and the other end boasts a plastic, segmented sensor wheel.

What I assume to be an optical sensor straddles the wheel, looking much like a disc-brake arrangement on a bike. This sensor monitors the motor speed and feeds data back to the control panel and/or motor driver.

The motor driver PCB is bolted to the metal floor of the motor bay on a solid, right-angled aluminium heatsink. I thought that this was where the problem lay, because this part does the lion's share of the work, and likely wears out first. Plus, I read a few forum posts where 'experts' postulated that failed motor driver boards are the cause of most powered treadmill failures.

The sticker on the motor states it is rated for 90-180V DC. That's some serious juice, and given it has to drive the belt with someone weighing up to 140kg standing on it, impressive in itself.

My research on the web revealed some generic circuit diagrams, but nothing matched this setup.

However, it appears that most powered treadmills use very similar technology to control the motors, and given there are only three types of motor typically used in treadmills, and two of those types are relatively rare, I could safely assume this controller is a PWM type. The PCB assembly certainly looked very similar to images of PWM boards I found online.

Taking the easy pickings

As the motor can be tested using a car battery or bench supply, that's where I started. I first had to pry the glue off the connections, then wired one of my workshop power supplies directly to the motor.

I dialled in some current and then gradually raised the voltage until the motor started to spin. I got up to about 15V, and as the motor was humming along nicely, I considered it to be serviceable.

Avoiding (for now) the glue-fest that is the motor driver assembly, I took the path of least resistance and removed the upper control panel, which is only held in with nine PK-type screws. These are easily accessible from the underside of the panel and once removed, the whole assembly lifts out from the top.

And of course, because all the flying leads, sockets and plugs that connect the panel to the rest of the treadmill are dripping with glue, it took a lot longer than it should. Once free, though, I could at least take it to my workbench, making it much easier to work on.

I'd singled out the data cable from the motor bay to the control panel from the loom going up the tubular frame and found it connected via a four-pin plug. Two of the wires were

black and red, so no prizes for guessing where to connect a power supply for testing!

With 12V applied from my bench supply, the panel lit up, and all the familiar displays were working aside from the main display cycling through several errors codes (probably relating to the lack of sensor and data connections).

I wasn't too bothered about what these error codes meant... yet. For now, all I needed to know was the display was working, so I reassembled it temporarily back into the treadmill and moved on.

Everything so far was pointing toward that motor control board. Removing it was as simple as taking out the two machine screws holding the heatsink to the deck, and then, of course, prying all the glue off everything connected to it.

On the bench, I began by removing the single huge 500µF 450V electrolytic and testing it, simply because it was the easiest potentially-suspect component to get at. It measured 0.05Ω ESR and 490µF on my Peak ESR tester. So no problem there.

I then removed the semiconductors from the heatsink so I could more easily reach and test them. All are stacked side-by-side and clamped to the heatsink with strips of metal and screws and lashings of thermal grease. There is a bridge rectifier in a SIL package, a dual diode array in a TO-220 package and an IGBT in TO3P format, all clearly identified.

The bridge rectifier tested fine, as did the diode array, but I couldn't test the IGBT with my Peak semiconductor tester. So I had to use the diode test function on my digital multimeter.

IGBTs are quirky things to test; with the negative lead clipped to the emitter, and the positive lead on the collector, there should be nothing, until a brief touch to the gate with the positive lead turns the transistor on. Then a measurement can be made across the collector/emitter junction. If the gate and collector are then shorted with a fingertip, the junction should reset, and the meter measure open circuit again.

In this case, the only measurement I could get on any pin combination, with any lead polarity, turned out to be the forward-bias of the fast-recovery diode. Also-called a 'freewheeling diode', according to the 18-page datasheet, it is connected internally in 'anti-parallel' across the collector/emitter junction and provides both faster switching recovery and inductive reverse current protection.

A potential fix

At least now I knew what could be wrong. After yet more internet searching, I found replacement IGBTs readily available from local suppliers and AliExpress, with the usual crazy price disparity.

I also found a vendor on AliExpress selling replacement boards, identical to this one. Interestingly, they were meant for Reebok-branded machines in the USA, so it seemed that there was some badge engineering going on. They were asking a couple of hundred dollars, which isn't too bad considering.

A dead IGBT might be just the tip of the fault iceberg, and I could be wasting my time sourcing and replacing it rather than just swapping out the whole board, which given my lack of treadmill servicing chops, might also not be the problem!

But sourcing anything from overseas would take at least two weeks, and while the IGBTs were available locally, they cost six times as much as the parts on AliExpress. But nothing is being shipped until we are out of level four lockdown, which will be at least two weeks away, so we are hammered either way.

And by then we'll likely be done and dusted with lockdowns and can get back to real walking, with the poor old treadmill being relegated back to hanging clothes and junk storage. This is one of those rare cases where I know what the problem is, but there's no straightforward way to resolve it.

It's a disappointing end to the tale, but fear not, I shall order a replacement part just as soon as I can and relate whether that did the trick. Fingers crossed, it will.

Clipsal C-Bus home automation system repair

About 18 months ago, D. S., of East Melbourne, Vic purchased a house with a fairly large Clipsal C-Bus installation controlling all of the lights, blinds and sundry other things in the house. It's a good thing that he is a retired electronic engineer, as it wasn't long before the system started to malfunction...

The home automation system in our house includes multiple touch panels, many wallplate buttons, motion sensors etc. When I saw how complex it was after moving in, I decided to do some research on how the system worked, just in case something went wrong.

All of the electrical devices to be controlled are wired back to three cabinets located next to the switchboard. The cabinets contain a mixture of DIN-rail mounted main units: three 12-channel relay units and six 8-channel dimmer units.

The C-Bus system consists of an Ethernet-like pink cable that connects in daisy-chain fashion to all of the control inputs – switches, motion sensors and touch panels. All of the input devices are connected in parallel and are powered from the C-Bus.

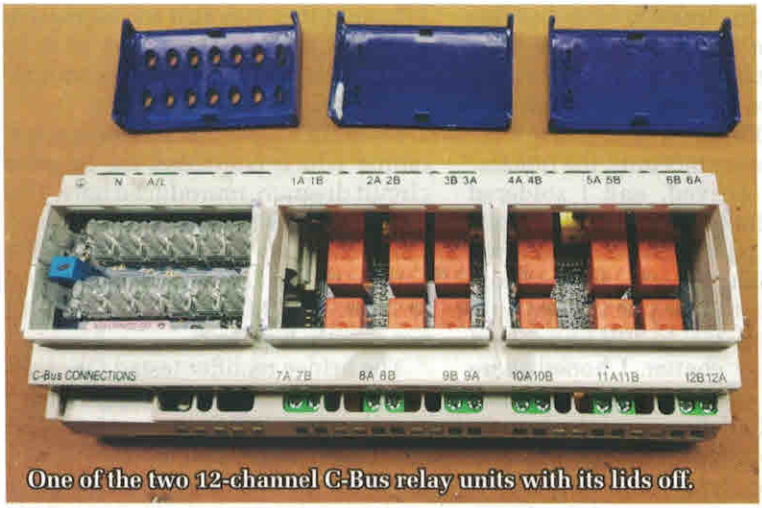
Although the C-Bus cable looks like an Ethernet cable and uses RJ45 connectors, it is not at all compatible with Ethernet. It uses a single, duplicated pair and the signalling is superimposed on the DC supply.

The C-Bus power (nominally 35V) is supplied by some of the units; they can optionally contain a 200mA power supply, at extra cost. The installer works out the total power requirements of all the input devices, then uses the required number of powered units to meet that requirement, when paralleled.

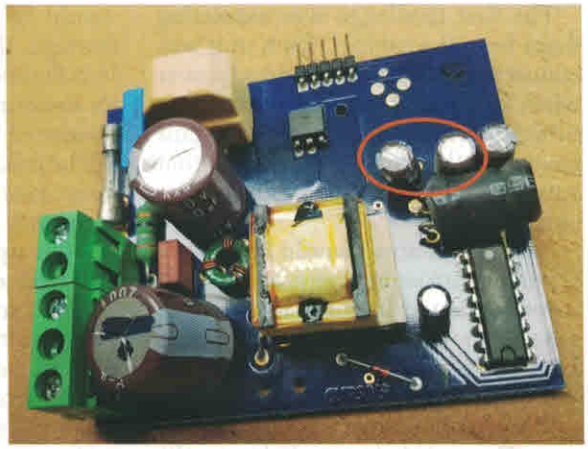
Up until recently, the system performed flawlessly, and my tinkering has been limited to minor reprogramming of the touchscreens for new LED lights. However, we came home one rainy night to be greeted by darkness. Cursory checks showed there was still power to the house, but the C-Bus system was completely out of action.

A check in one of the cabinets containing the C-Bus main units showed the C-Bus status lights were all off, indicating a problem with the bus itself. Two of the 12-channel relay units were chattering away with their lights blinking randomly. This should have been a major clue but, you know...

I disconnected the C-Bus cable from the top of one of the relay units (which is also the connection to the upper floor of the house). The chattering stopped, and the C-Bus status lights flickered back on. So, my immediate thought was that there was possibly a short upstairs, perhaps caused by the rain.



One of the two 12-channel C-Bus relay units with its lids off.


Above: the power supply board had failed with two 'dried-up' electrolytic capacitors.

I chopped an old Ethernet cable in half and made up a test plug. With a meter connected across the data wires, I checked the C-Bus voltage with only half the network running (34V) and with the full house plugged in (10V). The minimum acceptable voltage is 20V, so, it seemed my hunch could be right.

However, a resistance check of the upstairs section showed around 27kΩ, which seemed reasonable. Was it breaking down with voltage applied? I tried connecting a 27kΩ resistor across the bus to roughly simulate the additional DC power loading of the upstairs section, and the system continued to run OK. That eliminated the power supplies as the problem, or so I thought.

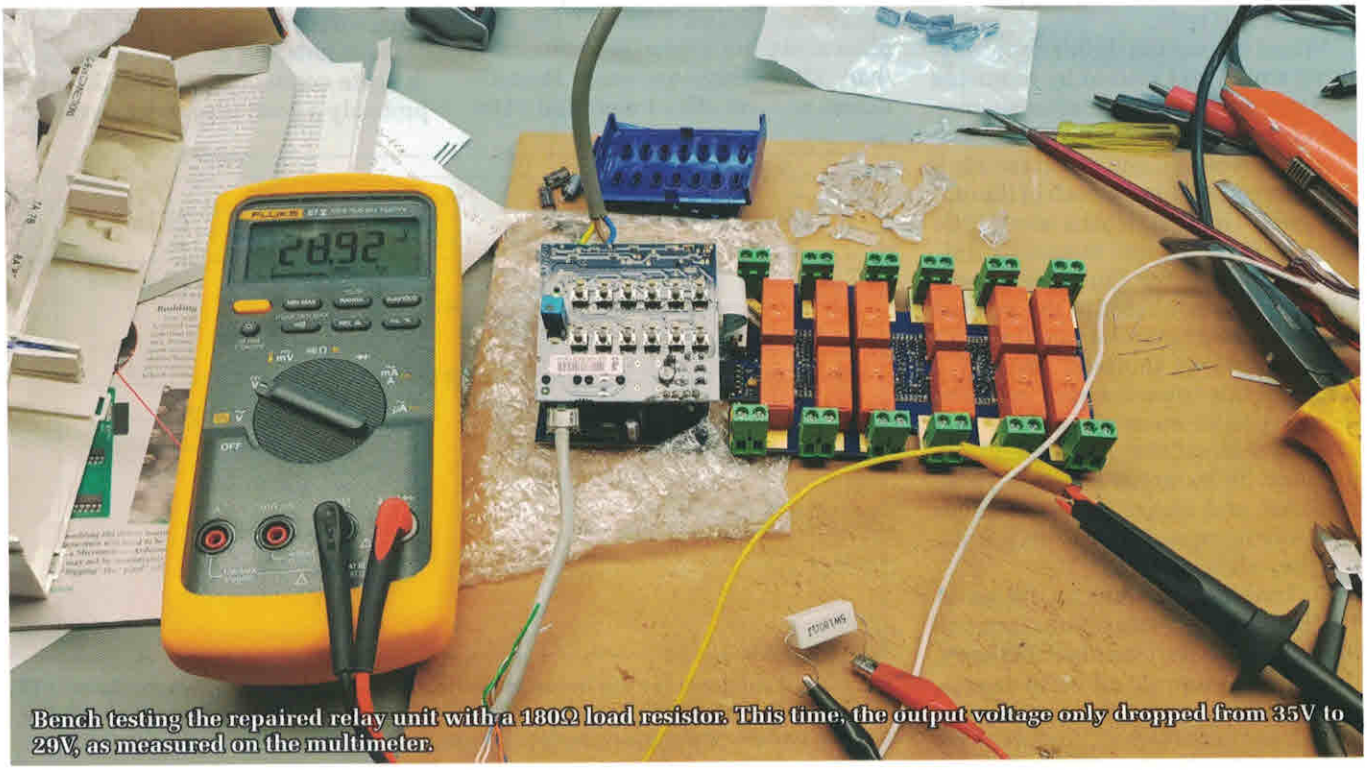
Anyway, after a fruitless day fiddling with re-connecting parts of the bus in the upper storey and finding that the system just became less and less reliable, I went back to have a closer look at the power supplies.

The three relay units and two of the dimmer units have an optional power supply, so I disconnected each one and tried a 180Ω test load on them individually.

Three of the units in the lower cabinet held up well, only dropping a few volts under load. But the two 12-channel relay units that had initially been chattering went berserk when the load was connected, with lights flickering out and relays clicking.

So, it seemed like the real problem was that the power supplies in those two units were faulty, leaving the input devices with only about 3/5 of their total power requirements.

Looking online, the RRP of these units is over $1500, so merely replacing them was an expensive option. A manufacturer's label showed they were barely nine years old, so should have life left in them. They were showing symptoms of dried-up electrolytic capacitors (a fault which will be familiar to readers of this column!). So a repair attempt seemed like a good option to me.



Bench testing the repaired relay unit with a 180Ω load resistor. This time, the output voltage only dropped from 35V to 29V, as measured on the multimeter.

The first challenge was extracting them from the cabinet. Each unit was connected to 24 power wires, power wires for the unit itself plus two C-Bus cables. Fortunately, there is a circuit breaker at the end of the DIN rail that cuts power to the entire unit and its peripherals.

I wondered how I would keep track of which wire went where, but the stiff wires remained in correct alignment even after they were disconnected from the unit. Finally, the first unit was out and on the bench.

The next challenge was opening the case. The case is in two halves, split vertically along the middle. There are clips along the bottom of the case, with three blue covers clipped on the top that hold the two halves together.

The blue covers proved to be a real battle. They slide into vertical channels and have lugs to hold them in place. However, some genius at the factory had decided to add dobs of plastic glue to make these covers almost unremovable. It took about an hour of levering and battling with various screwdrivers to finally crack the glue before I could get the covers off, with some battle scars to both the covers and the case.

The innards are divided into three boards: a large relay board, the C-Bus controller board and a power supply board. The power supply turned out to be a simple switching supply with three output rails.

Visual inspection didn't show anything amiss, so I started by removing and testing the mains filter capacitors, which measured OK.

Next, I removed and tested the 22µF 63V filter capacitors on each of the output rails. The first, which was a little raised off the board, measured 0nF. For the second, my Fluke meter read OL, which is not listed in the manual as a valid measurement (no, it wasn't still charged, or shorted). Anyway, I assumed this capacitor was bad. The third capacitor measured OK.

So, it seemed that I had found the problem. To be on the safe side, I also removed and tested the three other electrolytic capacitors on the boards, but they all tested OK.

So, I ordered six Nichicon PW-series 105°C replacement capacitors (same as the originals) for overnight delivery, intending to replace all three capacitors in each unit, on the assumption that if one lot was bad, the other lot would be too. Indeed, after battling through the same difficulty getting into the second unit, the same capacitor measured 0nF, while the other two measured OK.

The following morning, the replacement parts arrived, and I soldered them into the boards. With the units hooked up on the bench, I used my test cable and resistor to load them up.

This time, the output voltage only dropped from 35V to 29V under load with no relay chatter. I hoped there weren't any other hidden problems.

I re-installed the units into the cabinets, re-connected everything and switched on with fingers crossed. With some relief, I saw the lights come back on, and everything was back to normal.

The two units that failed are at the top of the upper-most cabinet, so probably had the highest heat loading. Nevertheless, there are three other units with power supplies which may also need repair in the future. I've ordered some additional capacitors, just in case.

Sharp R350Y microwave repair

R. S., of Fig Tree Pocket, Qld was not happy with the price he was quoted for a replacement module, so he decided to fix that module instead. That's often the only economical option these days, as he explains...

The inverter in our Sharp R350Y microwave failed. I looked for a replacement, but a new one costs more than $300. There are some reconditioned ones on eBay for around $100. I thought that was still too expensive so I thought I'd have a look at it, to see if it was repairable at the component level.

I found a copy of the service manual online which contained the inverter circuit diagram, reproduced here. The control unit is shown as a black box. I'm not sure why since the control ICs consist of two LM339 quad comparators and one LM324 quad op amp; it's not exactly high tech.

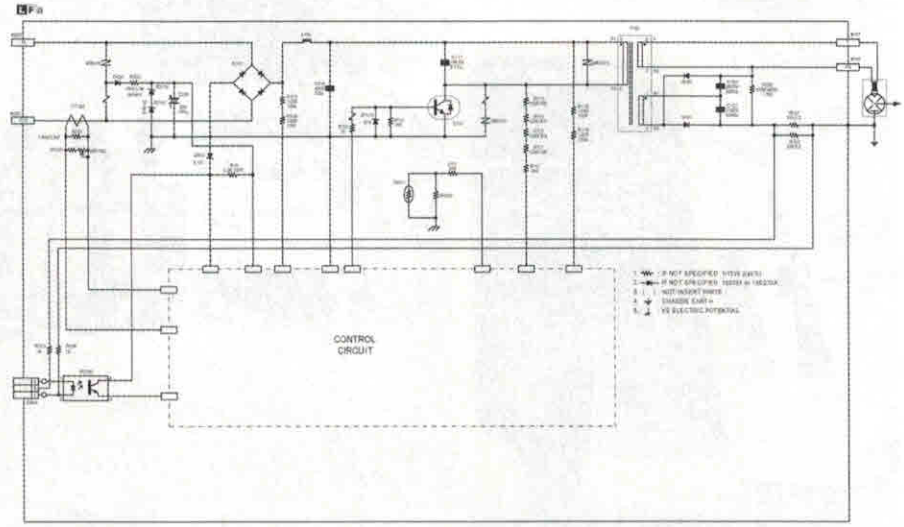
The bridge rectifier tested OK. I applied power and checked the gate drive signal to the IGBT Q110, and it looked OK. I used a low-cost battery oscilloscope for this, as this circuit operates at a high voltage relative to Earth. This IGBT is a Toshiba GT40T321 rated at 1500V, 40A and is available on eBay in pairs, at around $3 each.

The drive signal to the IGBT from the control circuit is buffered by a pair of complementary (NPN/PNP) transistors, not shown on this circuit because it's part of the control system.

To be safe, I replaced both gate drive transistors, the IGBT and the 10Ω IGBT gate series resistor. I also checked that varistor VRS110 (TVR10102) between collector and emitter of the IGBT was still connected.

I found that a PCB track to one side of the varistor had burned off the board, so I repaired that. The other varistor, VRS111, is not fitted to the board, as indicated by brackets on the circuit diagram.

I also checked for track damage on the gate connection to the IGBT. It is probably a good idea to leave the col-



The circuit diagram for the inverter section of the R350Y microwave, the text in the diagram is so small it can't be reproduced at a reasonable size, so check the manual online: www.manualslib.com/manual/677215/Sharp-R-350y.html

lector of the IGBT disconnected until you check that the gate drive looks OK, with square wave pulses of about 15V peak.

It seemed all right, so I reassembled the microwave, put a glass of water inside and heated it for a couple of minutes. The water started boiling, so that had obviously fixed it.

You can find the manual for this microwave at: **www.manualslib.com/manual/677215/Sharp-R-350y.html**

Editor's note: I paid less than $300 for a brand new 1200W microwave with inverter control. No wonder so many appliances wind up at the tip when replacement parts are so expensive.

Fridge repair from Russia

J. L., of Orange, NSW was visiting an Australian couple who live in the far east of Russia and they happened to mention that their son's fridge was not working properly. Being an old fridge tech, he kindly offered to help...

My friends' son was expecting the first addition to his family, so a working fridge was a necessity in a Russian summer. Hence they were about to buy him a new fridge. But I said I would have a look at it first, to see if I could save them the expense. Their son only lived a few blocks away so it was convenient enough and we popped around.

The fridge was a very old Japanese model which was powered using a step-up transformer – apparently, the fridge was made for the Japanese market but ended up in Russia, hence the different voltage requirements. The freezer compartment had some cooling, but the refrigerator compartment had none. The fridge was a "frost-free" design.

A frost-free fridge has a fan which circulates air through a hidden cooling coil and discharges the cooled air into the freezer and refrigerator. Frost forms out of sight on the cooling coil, which is automatically defrosted several times each day, to keep the coil clear of ice, allowing the air to circulate.

The defrosting process is initiated by a defrost time switch, typically every six hours. The defrost timer stops the compressor and initiates an electric heating element to melt the frost off the cooling coil. Heating continues until a small disc thermostat attached to the cooling coil senses a temperature high enough to indicates all the frost has been removed (typically around 6°C).

The "frost-free" fridge which had a broken thermostat.

The heating element then switches off and the fridge sits idle until the defrost timer runs out (typically after 30 minutes), allowing the compressor to start again, cooling the coil back down.

I removed the back panel of the freezer compartment to check the coil. The coil was mostly clear of ice, indicating that the defrost system was working but the build-up of ice at the top of the coil suggested that the defrost thermostat was terminating the defrost action before all the ice was gone.

With a little ice left over after defrost, the ice accumulated more each day and finally, the airflow became blocked and the fridge could not cool anymore.

I tried a non-traditional fix, relocating the defrost termination thermostat to a higher location on the cooling coil, but after a week it was clear that the ice build-up problem was fast returning.

Getting another defrost thermostat proved impossible in the far east of Russia – we just got that "idiot American" look from the servicemen to whom we spoke. Even if they had a thermostat to sell, I don't think they would have sold it to us on principle.

On the way home from searching service stores, the father said he had a couple of old fridges he was given to support the family's work with orphans, but the fridges had died because of city power supply problems. Could one of these fridges have an equivalent part that I needed?

After dismantling one old fridge, it turned out to be a frost-free style – the style I needed – and so I went searching for the defrost termination thermostat. The fridge was a Russian-made model but the principle of operation is the same everywhere with old fridges, so I removed the part and began testing to see if it would do the job.

The test was to soak both thermostats in the freezer compartment of a working fridge, to simulate normal fridge conditions. I removed the thermostats to the kitchen table, to gradually warm up, and with an ohmmeter, I was able to determine that the Russian part needed a higher temperature to open the circuit (and end the defrost operation) than the original thermostat.

The actual operating temperature was not important but the fact that it was a higher temperature than the original thermostat was a definite plus. The Russian defrost thermostat would mean the defrost element would operate longer than previously and should ensure all the ice is defrosted.

So I fitted the Russian part into the old Japanese fridge. Fortunately, defrost termination thermostats are a fairly standard design, a pre-set bimetal disc around the diameter of a 10¢ coin.

Fitting it was a breeze. I fired the fridge up and it seemed to work fine for the remaining week I was in Russia. Two years later and the old Japanese fridge has not missed a beat.

It's a great feeling to have beaten the odds with some thinking outside the square to produce a lasting, good result at no cost. I was the hero for a while and "the fridge job" still gets trotted out periodically to visitors! SC

ROADIES' TEST SIGNAL GENERATOR

by John Clarke

This test oscillator is ideal for testing balanced and unbalanced inputs on professional sound equipment. It's small, rugged, very portable and easy to use. It's powered by a single cell and is built to withstand use in a 'roadie' environment. Its frequency is fixed, but the output signal level is adjustable.

Sound reinforcement systems in public venues typically have a set of 3-pin XLR (eXtension Line Return) sockets providing a connection point for microphones. Instruments usually connect via a DI (Direct Input) Box or using an unbalanced lead.

Over time, these connections can become unreliable or go faulty.

Problems that can occur include bad connecting leads, poor XLR socket connections, broken wires or shorts. Finding where the problem is located may be difficult.

That's because the pathway from the XLR socket to a mixer can be long and can pass through separate patch boxes before finally making its way to a mixer.

There are many ways of tracing faults. You can simply use a microphone or instrument as a signal source and test for sound from the loudspeakers or headphones at the mixer.

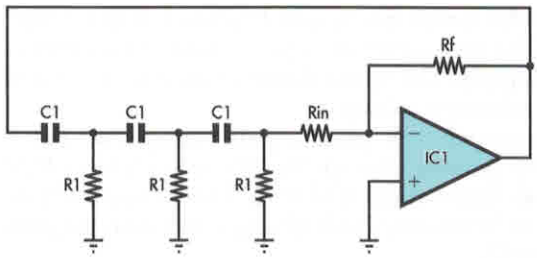
But then you need to have somebody standing there speaking into the microphone or playing the instrument while you trace the fault; not exactly ideal. It's much easier to use a test oscillator as the signal source.

This oscillator provides a signal level that is constant and continuous. That makes it easier to get on with the job of finding the trouble spot.

Our Roadies' Test Signal Generator is a small unit that's powered from a lithium button cell. The housing is diecast aluminium so that it can take some punishment; the only exposed parts are the outlet socket and a potentiometer knob for adjusting the signal level.

The oscillator output is around 440Hz ("A") – not so high that it's irritating, but high enough that it can be clearly heard over background noise.

There is no on/off switch as such, since it is switched on automatically when a



TRADITIONAL PHASE-SHIFT OSCILLATOR

Fig.1: a traditional phase-shift oscillator uses three RC high-pass filters in the feedback loop of an op amp (or similar amplification device) with sufficient gain for oscillation to start up and then be maintained, but not so much gain that the output becomes squared off.

FEATURES & SPECIFICATIONS

- Generates 440Hz sinewave at 0-1.2V RMS (adjustable)
- Single-ended or impedance-balanced output via a 6.35mm jack socket
- Auto on/off switch
- Powered by a lithium button cell
- 60 hours of use from a single cell (3.5mA current draw when on)
- Compact & rugged
- Easy to build (two versions depending on constructor skill level)

jack is plugged in, as happens in much professional audio equipment.

This eliminates the possibility that it can be accidentally left on after it is unplugged, or accidentally switched on when it is jostled, draining the cell of all its power.

Two versions

We have produced two versions of the Roadies' Test Signal Generator. One uses surface-mount components so that the PCB is smaller and is housed in a more compact enclosure.

But if you prefer using through-hole components instead, you can still build it; you just need a larger case.

Circuit basics

The circuit uses a simple phase-shift oscillator based on op amps. These op amps can run from 1.8-6V and have a rail-to-rail output, so they are ideal for use with a 3V cell. They can provide a sufficient output signal level of around 0.7V RMS, even when the cell has discharged to 2V.

Fig.1 shows the configuration of a typical phase-shift oscillator. This typically uses a set of three resistor-capacitor (RC) high-pass filters, in conjunction with inverting amplifier IC1.

The gain of the inverting amplifier is made sufficient so that oscillation will start at power-up and is maintained.

With the correct amount of gain, the op amp output signal is a sinewave. Too much gain will cause the op amp to produce a squared-off waveform, with the tops of the sinewave clamped at the op amp maximum output.

So these oscillators require the gain to be calibrated for correct operation. That can be troublesome, especially when the supply voltage changes, as can happen in a battery-powered oscillator.

The oscillation frequency is $1 \div \sqrt{6} \times 2\pi \times R1 \times C1$.

Circuit details

The complete circuit is shown in Fig.2. The oscillator section is the components around IC1a at upper-left. You can see that this is a little different than what is shown in Fig.1; we are using RC low-pass filters and the amplifier is

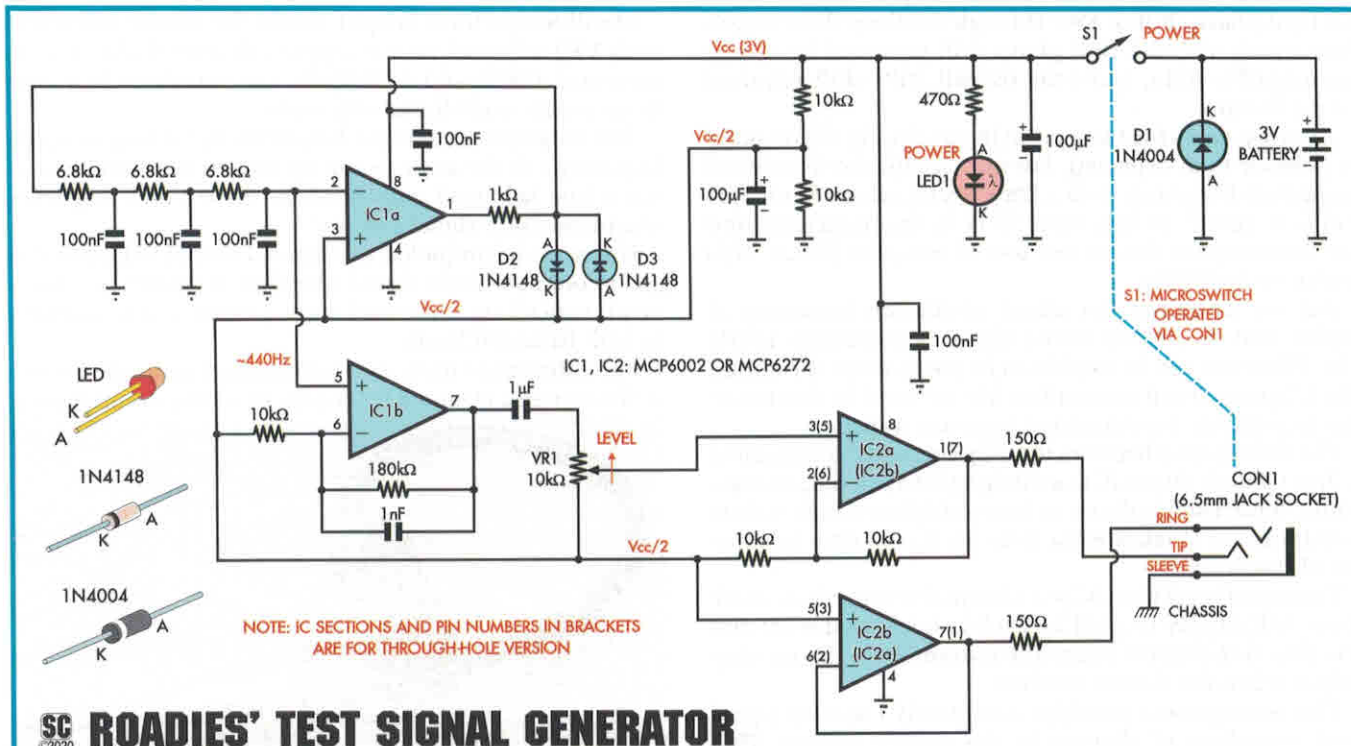
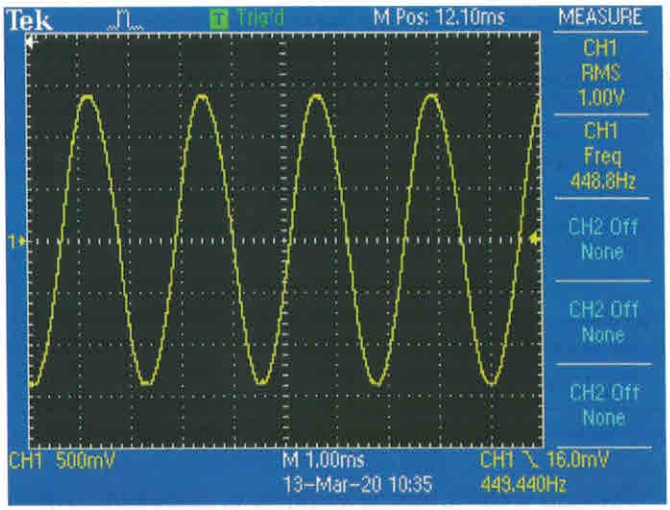


Fig.2: our circuit uses a slightly more unusual phase-shift oscillator with three low-pass filters in the feedback path and diodes D2 & D3 to limit the output swing to around 1.4V peak-to-peak. The signal is taken from input pin 2 of IC1a, as this is a sinewave, and amplified by op amp IC1b before being attenuated by VR1 and then fed to output socket CON1.



Scope1: this shows the output waveform with VR1 adjusted so the output just started clipping. It measures 448Hz and 1.0V RMS. The waveform is a relatively clean, undistorted sinewave.

not set at a predetermined gain. Instead, it is operated in open-loop mode, providing the maximum gain available from the op amp.

This means that the gain is more than sufficient for oscillation to start and to be maintained. The op amp output swings fully to the supply rails, so the waveform at IC1a's output is almost a square wave.

But there is a sinewave at the inverting input of op amp IC1a (pin 2), as this is the output signal after passing through the three low-pass filters. This is the reason for choosing low-pass filters instead of high-pass.

Oscillation normally stabilises at a frequency when there is a total phase shift of 180° through the three filter stages. This, along with the 180° phase shift provided by inverting amplifier IC1a, gives the overall 360° shift required for oscillation.

Anyway, that's the theory; but in our circuit, the frequency is lower than expected. For our circuit, the theoretical oscillation frequency is $\sqrt{6} \div (2\pi \times R \times C)$, where R is 6.8kΩ and C is 100nF. In this case, $\sqrt{6}$ is in the numerator and not denominator due to our use of low-pass filters. This works out to 573Hz.

But we measured the actual oscillation frequency at 448Hz, and simulation shows that it is nominally 435Hz (the difference can be explained by component variation). The LTspice circuit simulation file we used to determine this is available for download from our website.

The discrepancy between these figures and the calculated 573Hz value is due to IC1a switching into full output saturation, which slows down its low-to-high and high-to-low transitions, as it takes extra time for the op amp to come out of saturation.

The signal level from IC1a is clamped to a nominal ±0.6V about half supply ($V_{CC}\div2$) by back-to-back diodes D2 and D3. The 1kΩ resistor limits the current from the op amp output when the diodes conduct.

This arrangement provides a relatively constant signal level regardless of changes in the supply voltage. That can vary from 3V with a new cell, down to 2V when it is discharged.

The half supply rail ($V_{CC}\div2$) is formed by a 10kΩ/10kΩ voltage divider across the supply, bypassed with a 100µF capacitor. The non-inverting input to IC1a is also tied to this $V_{CC}\div2$ supply. The signal therefore swings above and below this reference voltage.

With a nominal 1.2V peak-to-peak swing from pin 1 of IC1a, after passing through the filters, we get a 78mV peak-to-peak signal at pin 2 of IC1a. This is amplified by a factor of 19 by op amp IC1b, giving 1.48V peak-to-peak or 525mV RMS.

The signal is then AC-coupled to level control potentiometer VR1. The lower portion of VR1 connects to the $V_{CC}\div2$ reference, so that there is no DC voltage across the potentiometer.

IC2a (IC2b in the through-hole version) amplifies this by a factor of two, so the maximum output can be up to 1.2V RMS, with just over 1V RMS available before clipping. This signal goes to the tip terminal of the jack socket.

Note that the IC2a (IC2b) output includes a series 150Ω resistor to provide isolation, so that the op amp isn't prone to oscillation with capacitive loads. That's extra protection for the already stable op amp (MCP6002), which has a typical 90° phase margin with a resistive load and a 45° phase margin with a 500pF capacitive load. If the MC6272 is used instead, the resistive load phase margin is 65°.

IC2b (IC2a in the through-hole version) provides a buffered $V_{CC}\div2$ output, also via a 150Ω resistor. This connects to the ring terminal of the jack socket. When there is no signal, with VR1 wound fully anticlockwise, both the tip and ring are at $V_{CC}\div2$.

Since the whole circuit is powered from a 3V cell, it floats with respect to any outside reference voltage, so this voltage can be grounded within the equipment being fed.

Balanced & unbalanced connections

Oscilloscope trace Scope1 shows the output waveform with VR1 adjusted so the output just started clipping. It measures 448Hz and 1.0V RMS. The waveform is a relatively clean, undistorted sinewave.

The output is impedance-balanced, ie, the ring terminal impedance is the same as the tip output impedance. It is not a true balanced output where the tip and ring have complementary signal swings.

However, the impedance-balanced output still provides good common-mode signal rejection at receiving equipment, cancelling noise and hum pickup that's common in both balanced leads.

For unbalanced lines, the ring connects to the sleeve and so the signal is from the tip connection. More information

The XLR-to-6.35mm lead we made up to suit this project (see Fig.8) also serves to turn it on and off: a tiny microswitch is activated when ever the plug is inserted in the socket.

The through-hole PCB mounts upside-down on the diecast case lid . . . which becomes the base! Its power LED, output socket and level control all poke through holes drilled in the side of the case. The panel label can be used as a template for hole locations.

on this configuration is available at siliconchip.com.au/link/ab10

For a balanced connection to the test signal oscillator, ideally you should have a lead with a stereo jack plug at one end and an XLR at the other.

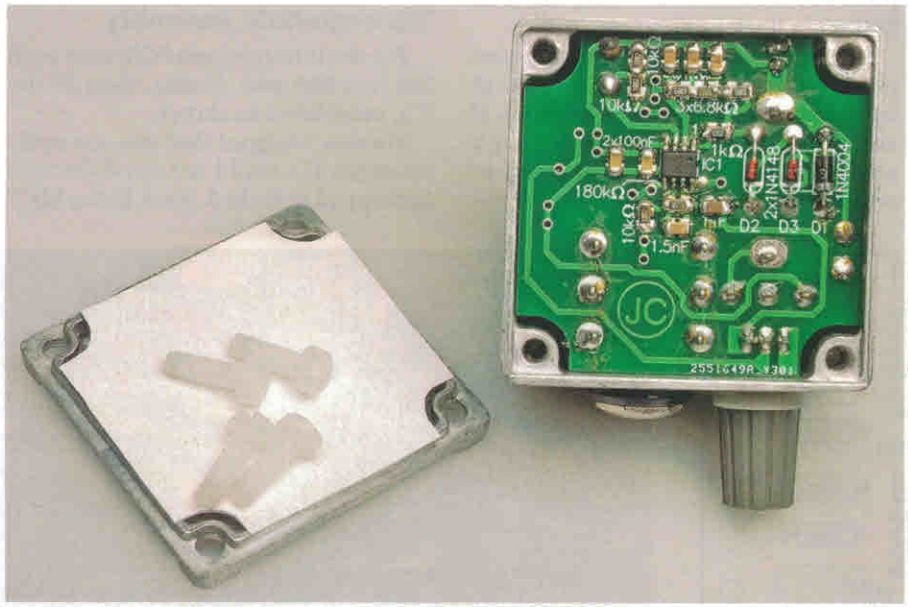
The jack tip should connect to pin 3 on the XLR, and the ring to pin 2. The sleeve would connect to the pin 1 of the XLR plug. Such cables are readily available, or you can make one up as per Fig.8.

For an unbalanced output, a mono jack plug to mono jack plug lead can be used. This automatically connects the ring to the sleeve within the jack socket.

As mentioned earlier, power is from a 3V button cell. Diode D1 provides reverse polarity protection as the diode will conduct with the cell inserted backwards. This can usually only happen if the cell holder itself is fitted the wrong way around on the PCB.

Construction

The smaller SMD version of the



The smaller SMD version is held in place by its input socket and level control, with a hole drilled through the case for the power LED to poke through. The panel label can be used as a template for hole locations. Also shown here is the card "insulator" to ensure none of the components or solder joints can short out to the case. Any type of card, or even thin plastic, is adequate.

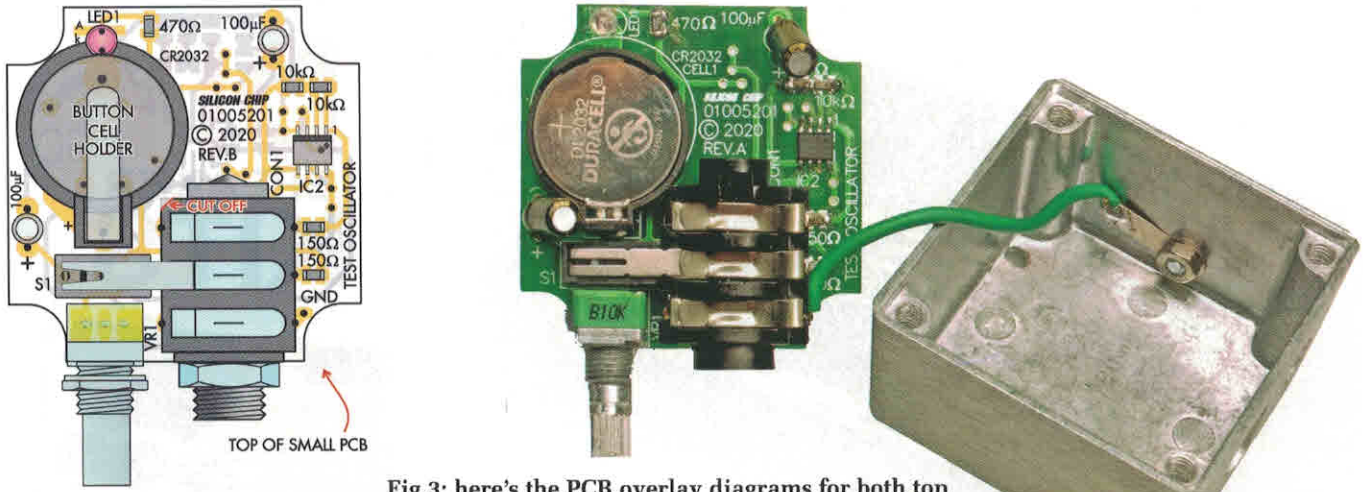


Fig.3: here's the PCB overlay diagrams for both top and bottom of the SMD version PCB, with a matching photo (of the top side) which also shows the microswitch to turn power on when the 6.35mm plug is inserted. Note the area of the 6.35mm socket which must be shaved off to clear the button cell holder (in red). Also shown is the case with the short ground lead in place – this is essential to prevent hum when you touch the case. It connects to the "GND" terminal on the PCB.

Roadies' Test Signal Generator is built on a PCB coded 01005201 which measures 47 x 47mm. This mounts in a 51 x 51 x 32mm diecast aluminium box.

The through-hole version is built on a PCB coded 01005202 which measures 86.5 x 49.5mm. It fits in a diecast box measuring 111 x 60 x 30mm. Figs.3 & 4 are the PCB overlay diagrams for the two versions.

SMD version assembly

For the surface mount version, many of the parts are on the underside of the PCB.

In this case, begin construction by installing the SMDs on both sides of the PCB.

They are relatively large, so they are not difficult to solder using a fine-tipped soldering iron. But good close-up vision is necessary so you may need to use a magnifying lens or glasses to see well enough.

Be sure that the ICs are orientated correctly before soldering all their pins. For each device, solder one pad first and check alignment.

If necessary, readjust the component position by reheating the solder joint before soldering the remaining pins. If any of the pins become shorted with solder, solder wick can be used to remove the solder bridge.

The capacitors are usually unmarked except on the packaging supplied with the parts. The resistors are marked with a code as shown in the parts list.

Diodes D1-D3 are through-hole parts. These are mounted and soldered form the underside of the PCB, with the leads trimmed flush on the top side. Take care to orientate each correctly before soldering. Now move on to the combined assembly instructions below.

Through-hole assembly

For the through-hole PCB, start with the resistors and diodes, then fit the ICs, orientated as shown.

We don't suggest that you use sockets as the ICs could fall out if the unit is dropped or kicked. Next, fit the MKT

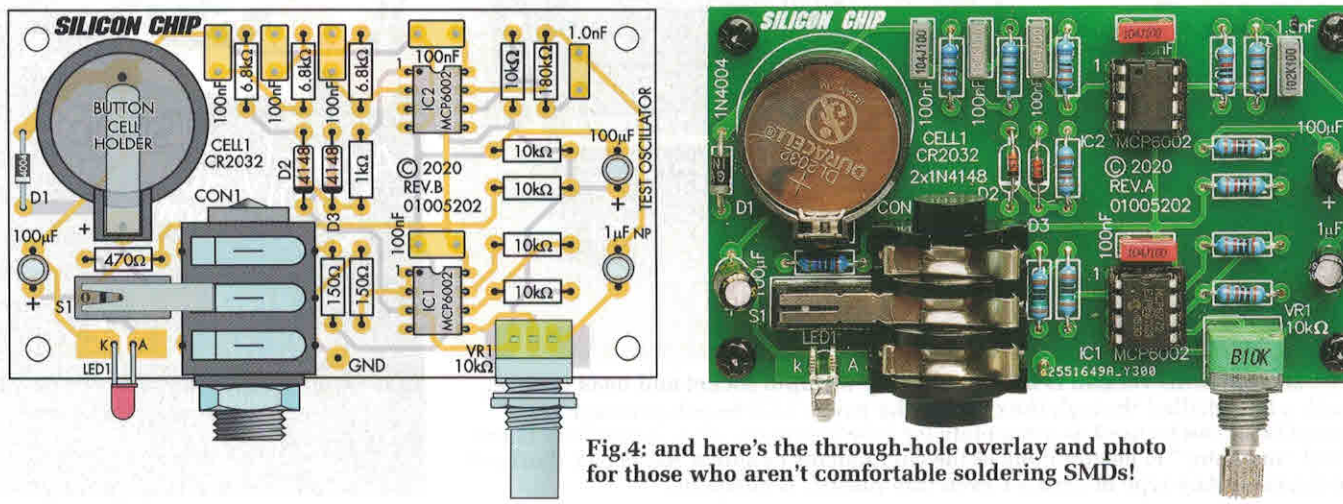


Fig.4: and here's the through-hole overlay and photo for those who aren't comfortable soldering SMDs!

Fig.5: make this insulating panel from thick card and insert it between the SMD PCB and case lid.

capacitors, which are not polarised.

Combined assembly

Now mount the electrolytic capacitors. Two of these are polarised, so they must be installed with the longer leads towards the + sign on the PCB.

Next, mount the cell holder with the orientation shown, followed by potentiometer VR1 and jack socket CON1.

But note that for the surface-mount version, a small section of the plastic case of the jack socket for CON1 needs to be cut off, so that it does not foul the cell holder. Fig.3 shows where to cut at 45°; this can be done with a sharp hobby knife.

Switch S1 is a microswitch which is mounted so that the lever is captured under the front ring contact of jack socket CON1. Before soldering it, check that the switch is open-circuit between its two outside pins when there is no jack plug inserted, and closed when a plug is inserted. The lever may require a little bending so that the switch works reliably.

For the through-hole version, mount LED1 so its body is horizontal and located so the centre is in line with the centre of the CON1 hole as shown. Make sure the leads are bent so the anode (longer lead) is to the right. The surface-mount PCB has LED1 arranged vertically, with the top of the dome 21mm above the top of the board.

Case assembly

We are using the lid as the base of the case for both versions. This gives a better appearance and also means that we can replace the lid screws with M4 Nylon screws (after tapping the holes to M4) to act as feet.

Changing the cell requires removing the PCB. That's not too difficult, and we don't expect the cell will need changing

Parts list – Roadies' Test Signal Generator

Parts common to both versions

1 panel label (see text)
1 CR2032 PCB-mount button cell holder
1 CR2032 cell
1 6.35mm stereo switched jack socket (CON1) [Jaycar PS0195, Altronics P0073]
1 C&K ZMA03A150L30PC microswitch or equivalent (S1) [eg Jaycar SM1036]
1 9mm 10kΩ linear pot (VR1)
1 knob to suit VR1
4 M4 x 12mm Nylon screws (for mounting feet – replace supplied case screws)
1 solder lug
1 90mm length of green hookup wire
1 1N4004 diode (D1)
2 1N4148 diodes (D2,D3)
1 3mm LED (LED1)
2 100µF 16V PC electrolytic capacitors

Parts for surface-mount version

1 double-sided PCB coded 01005201, 47 x 47mm
1 diecast aluminium case, 51 x 51 x 32mm [Jaycar HB5060]
1 M3 x 6mm countersunk screw (solder lug mounting)
1 M3 nut and star washer

Semiconductors
2 MCP6002-I/SN or MCP6272-E/MS op amps, SOIC-8 (IC1,IC2)
[RS Components Cat 6283598 or 6674492]

Capacitors (all 50V X7R SMD, 3216/1206 size)
1 1µF ceramic
5 100nF ceramic
1 1nF ceramic

Resistors (all 0.25W SMD, 1% 3216/1206 size)
1 180kΩ (code 1803)
5 10kΩ (code 1002)
3 6.8kΩ (code 6801)
1 1kΩ (code 1001)
1 470Ω (code 4700)
2 150Ω (code 1500)

Parts for through-hole version

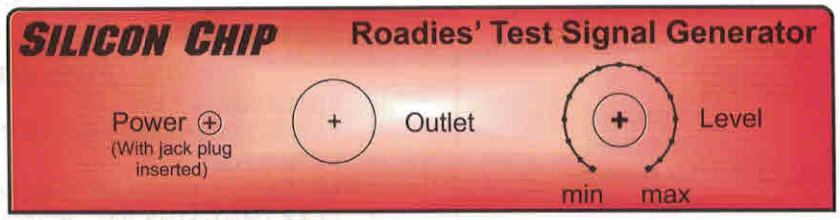
1 double-sided PCB coded 01005202, 86.5 x 49.5mm
1 diecast aluminium box, 111 x 60 x 30mm [Jaycar HB5062]
4 M3 x 6mm pan head screws (PCB to standoffs)
5 M3 x 6mm countersunk screws (lid to standoffs and solder lug mount)
1 M3 nut and star washer
4 M3 tapped x 6.3mm standoffs
1 PC stake

Semiconductors
2 MCP6002-I/P or MCP6272-E/P op amps, DIP version
[RS Components Cat 403036 or 402813] (IC1,IC2)

Capacitors
1 1µF 16V NP PC electrolytic
5 100nF MKT polyester
1 1.0nF MKT polyester

Resistors (all 0.25W, 1%)	***4-band code***		***5-band code***
1 180kΩ	*brown grey yellow brown*	*or*	*brown grey black orange brown*
5 10kΩ	*brown black orange brown*	*or*	*brown black black red brown*
3 6.8kΩ	*blue grey red brown*	*or*	*blue grey black brown brown*
1 1kΩ	*brown black red brown*	*or*	*brown black black brown brown*
1 470Ω	*yellow violet brown brown*	*or*	*yellow violet black black brown*
2 150Ω	*brown green brown brown*	*or*	*brown green black black brown*

HOLE SIZES:
Power LED: 3mm
Outlet Socket: ...11mm
Level pot: 7mm



Figs.6&7: front panel artwork for both versions of the Roadies' Test Signal Generator. As mentioned in the text, the artwork can be photocopied and used as a drilling template. (These can also be downloaded from siliconchip.com.au).

for years with intermittent use. Expect over 60 hours of usage from a good cell.

We have provided front panel artwork for both versions and many of the drilling positions on the diecast boxes.

These are shown in Figs. 6&7 and can also be downloaded as a PDF file from the SILICON CHIP website.

The hole for the 6.35mm jack socket is 11mm, the potentiometer hole is 7mm and the LED hole is 3mm in diameter. The panel artworks show the positions.

For the surface-mount version, the LED hole is on the top of the case. With this version, drill the holes at an angle so that the pot shaft and jack socket can be inserted more easily. The LED will need to clear the box edge without affecting its position.

Countersinking the inside of the LED hole will make it easier to locate the LED as the PCB is inserted into the case.

Both versions require a solder lug to ground the case.

For the through-hole version, this is located on the lid but is away from the underside of the PCB. You need to drill a 3mm hole for this, plus four for the PCB mounting posts.

The PCB is located centrally across the width of the lid, but the front edge is positioned so it is only 3mm back from the lid edge, so that the pot and jack socket are against the case edge when assembled.

We used countersunk screws for the standoffs and solder lug screws, and if you do the same, these holes will require countersinking on the outside of the case. Add a star washer against the solder lug before tightening the nut. Then solder hookup wire to one end to the solder lug and solder the other to the GND terminal on the PCB.

For the through-hole version, we use a GND PC stake fitted to the underside of the board to connect this wire. For the surface-mount version, the wire solders to the top side of the PCB directly to the GND pad.

The surface-mount version should have an insulator made from some stiff card added between the PCB and case lid (see Fig.5). This prevents possible shorting between the two.

As mentioned, M4 Nylon screws are ideal for mounting the lid. Tap each hole with an M4 tap before securing the lid with these screws.

Alternatively, you could use the mounting screws supplied with the case, and add small stick-on rubber feet.

Panel labels

The front panel labels can be made using overhead projector film with the printing as a mirror image, so the print will be between the enclosure and film when affixed.

Use projector film that is suitable for your printer (either inkjet or laser) and glue using clear neutral cure silicone sealant.

Squeegee out the lumps and air bubbles before the silicone cures. Once cured, cut out the holes through the film with a hobby or craft knife.

For more detail on making labels, see **www.siliconchip.com.au/Help/FrontPanels**

The potentiometer shaft is held in place using its washer and nut, while the 6.35mm jack socket is secured using the supplied washer, plastic dress piece and dress nut.

Testing and modifications

You can test the oscillator using a multimeter set to measure AC volts and connected to the output between the tip and ring connections of a stereo jack plug. Note that the output can produce clipping if the signal level is near maximum, so bring the level back a little for a clean sinewave.

The output frequency can be changed by altering the values of the three 6.8kΩ resistors in the low-pass filters or changing the values of the three associated 100nF capacitors. Smaller values will provide a proportionally higher frequency; larger values, a lower frequency. SC

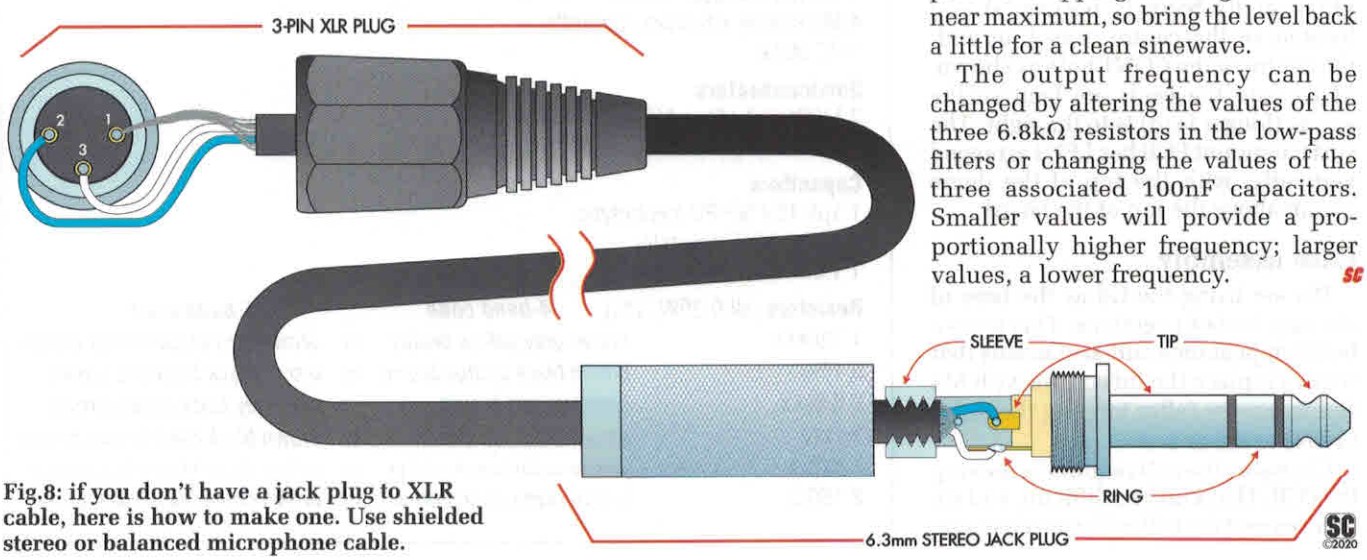


Fig.8: if you don't have a jack plug to XLR cable, here is how to make one. Use shielded stereo or balanced microphone cable.

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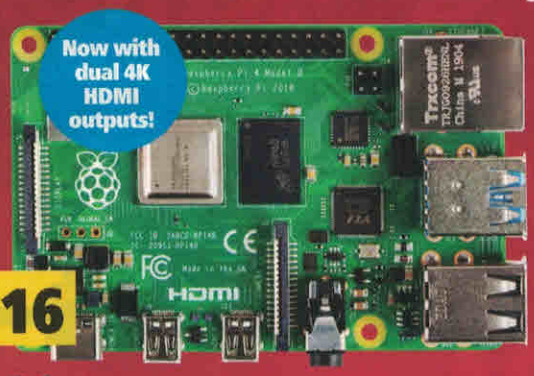

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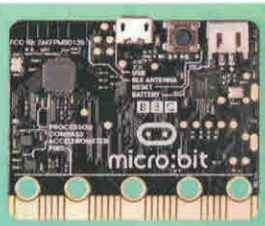

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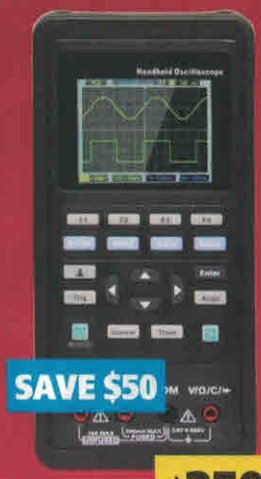

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Specialises in low current, high resolution readings down to 1mA. Suits AC or DC use up to 80A. Cat III 600V. 2 year warranty. Includes test probes for other multimeter functions.

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This workbench essential is just the shot for electronics projects, crafts, hobbies and odd jobs around the house! Powerful 130W motor with variable speed between 8000 and 33000 RPM. Included is a 172pc accessory kit of grinding wheels, drills, cutters, sanding discs, polishing pads and more! Stows away in a hard plastic carry case.

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T 5049 174x108x45
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T 5051 302x206x162
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T 5053 352x242x172
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$136
T 5055 412x302x182
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T 5056 452x352x192
Was $205.

$212
T 5066 521x292x183
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K 1148

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A six legged robot kit designed to avoid objects or follow you around the room. Easy to build. Interactive AI develops its own emotions and gestures. Requires 4 x AAA batteries (S 4949B $9.95).

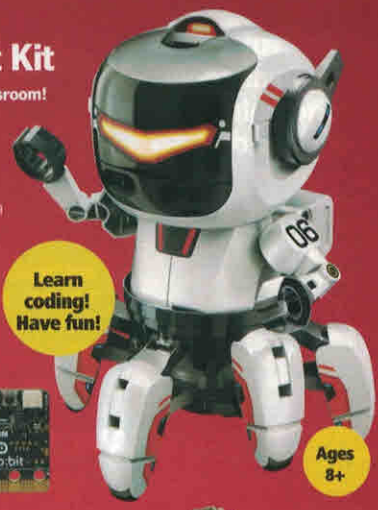
Tobbie II Robot Kit

A great STEM robot for the classroom! Tobbie is back and he's had an upgrade! Now powered by the popular BBC micro:bit board, this new version has unlimited scope for self programming. Front screen displays text & symbols. Great for teaching kids coding. Requires 4xAAA batteries (S 4949B $9.95) and BBC micro:bit board.

$60 K 1150

SAVE $9.95

or $89 with BBC micro:bit board (Z 6439). SAVE $12



SAVE 17%

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K 1113

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A fun and educational kit designed to assemble 14 different ways to inspire your kids to learn about solar power. No soldering required. Requires no batteries. **Ages 8+**

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White 5050 Indoor	X 3210A	$56.95	$44
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White 3528 Outdoor	X 3206A	$43.75	$34
Warm White 5050 Outdoor	X 3211A	$68.95	$54
White 5050 Outdoor	X 3212A	$68.95	$54
Blue 5050 Indoor	X 3209A	$62.75	$52
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B 0092

PRODUCT SHOWCASE

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Laird Connectivity Sentrius IG60-BL654 Starter Kit with Three Bluetooth 5 Sensors

The Laird Connectivity Sentrius IG60-BL654 and BT510 Starter Kit, available from Mouser Electronics, includes the Sentrius IG60-BL654 gateway with Amazon Web Services (AWS), plus three BT510 Bluetooth 5 sensors.

Engineers can gather data from the BT510 sensors and collect the data with the IG60-BL654 gateway before sending it to the cloud via AWS IoT Greengrass, while available iOS and Android mobile apps enable fast, in-field provisioning.

Based on Laird Connectivity's 60 Series system-on-module (SoM) and BL654 embedded Bluetooth module with Nordic Semiconductor nRF52840 system-on-chip (SoC), the IG60-BL654 provides a powerful platform for Bluetooth 5 long-range sensor-to-cloud applications.

The combination of Bluetooth and Wi-Fi allows customers to capture data from Bluetooth 5 sensors, add edge intelligence, and send that data to the cloud over high-performance 802.11ac Wi-Fi.

Contact:
Mouser Electronics
Unit 701-3, 7F, LU Plaza, 2 Wing Yip St
Kwun Tong, Kowloon, Hong Kong
Web: www.au.mouser.com

Wearable Electronics and the Healthcare Market

While traditional electronic systems have an inherently rigid form factor, developments in manufacturing processes and materials are enabling a new world of flexible electronics. Just last year several foldable smartphones were revealed to the market.

In a new research report titled "Flexible Electronics in Healthcare 2020–2030", IDTechEx analysts find significant opportunities for flexible electronics to be applied to healthcare. In this report, IDTechEx forecasts the market for healthcare products containing flexible electronics to be worth over $8.3 billion by the year 2030.

One way to address patient adherence to monitoring is to make the device unobtrusive to the point of invisibility. Electronic skin patches, wearable devices that are electronic components adhered to the skin, are one such way to address this.

Read the detailed report at www.siliconchip.com.au/link/ab2f

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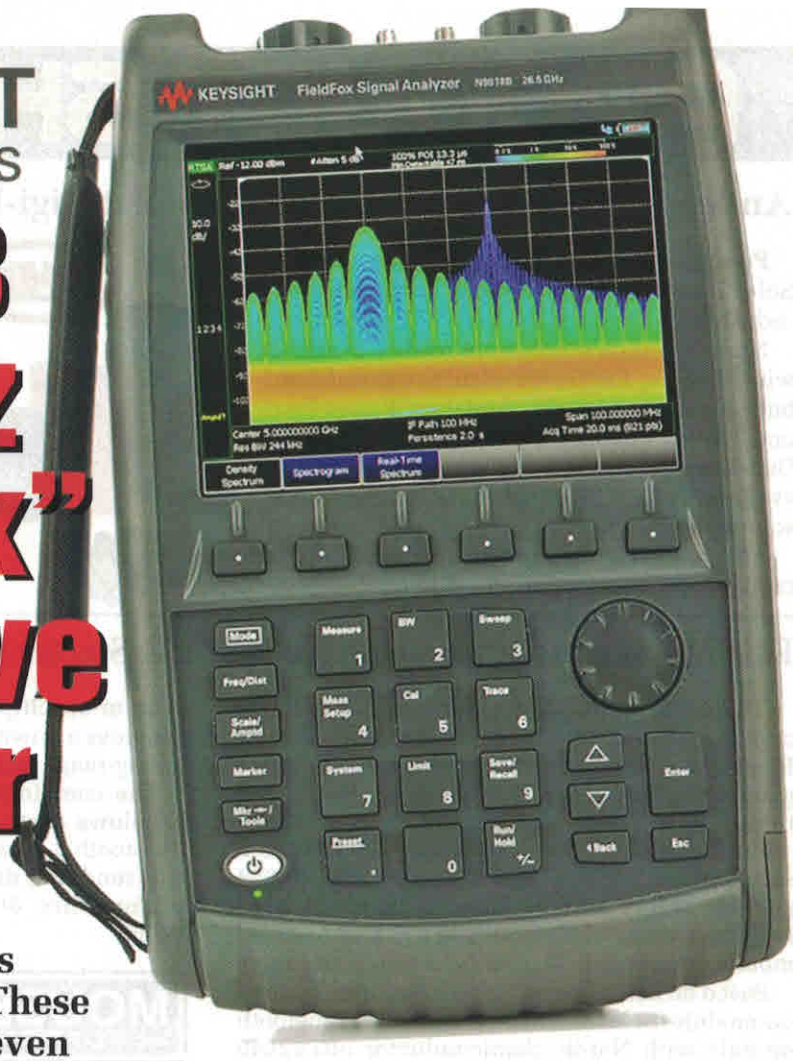
KEYSIGHT TECHNOLOGIES

N9918B 26.5GHz "FieldFox" Microwave Analyser



Keysight's FieldFox range of handheld microwave analysers have impressive capabilities. These have recently been expanded even further; in particular, adding the 100MHz real-time bandwidth necessary to work with the new 5G mobile technology.

We reviewed Keysight Technologies' N9917A Network/Spectrum Analyser in our June 2017 issue (siliconchip.com.au/Article/10686).

We found it to be a comprehensive piece of test gear, providing many features useful to those working in RF fields. Depending on the options installed, its main functions include:

- Spectrum analyser
- Real-Time Spectrum Analyser (RTSA)
- Vector Network Analyser (VNA)
- Vector voltmeter
- Time Domain Reflectometry (TDR)
- Extended Range Transmission Analysis
- Interference analysis
- Cable and Antenna Analyser (CAT)

Our previous article gave an overview of what these functions are and how they can be used. As we noted in that article, we do not have the experience or test equipment to do justice to such a specialised and advanced piece of equipment.

If we had kept that one, it would probably be the most advanced piece of test gear in our laboratory. The same comments apply to the newer Analyser we are reviewing here, but even more so.

The N9917A is touted as a handheld unit, but it weighs 3kg, so you probably won't want to be holding it all day (unless you particularly want a forearm workout!). It is clearly quite rugged though; that's important for a tool that could be used frequently 'in the field' and exposed to very trying conditions.

A side strap makes it easy to carry and hold, and there is a folding stand to allow it to sit on a flat surface at a comfortable working angle.

It has an internal, removable rechargeable battery for portable operation. The large LCD screen is supplemented by a comprehensive backlit keypad with large keys, meaning that the device is easy to use, even with gloves on.

Three sides of the unit are decked out with various ports. The top sports the two main RF ports, an input for a GPS antenna and the external reference or trigger input.

The right-side features an assortment of computer interfaces, including LAN, USB (device and host) and an SD card

Review by Tim Blythman

socket. These ports are protected by separate gasketed doors.

The left side has connections for DC power to run the unit and charge the battery (provided by an external supply similar to a laptop PSU), bias power out and a headphone jack. There is also a speaker. The audio output can be used when working with AM and FM broadcasts, to listen to the demodulated audio.

The space below these ports along the left-hand side leaves the perfect area to grasp the unit with the help of the side strap.

New features

The N9917A was – and remains – a very capable and well laid out piece of test gear, and would be well at home in the hands of even the most experienced RF engineer.

Being from the same FieldFox range, it is no surprise that the N9918B looks similar to the N9917A that we reviewed previously. In fact, apart from the part number designation above the LCD screen, outwardly, the unit is otherwise identical.

But there are differences. Table 1 shows the main difference in characteristics between the two units. As noted, the Maximum Real-time Bandwidth is now 100MHz up from 10MHz, but this is not the only change. Many of the other RF performance parameters, such as dynamic range, sweep speed and attenuator range have been improved.

So, while the outward appearance is much the same, we would not be surprised if the hardware RF internals are quite different.

Like the N9917A, many of the features are optional. That includes the 'headline' 100MHz real-time bandwidth (there is also a 40MHz bandwidth option; the default is still 10MHz). The only standard feature is the Cable and Antenna Analyser. Most options do not have to be selected at purchase time, but are simply enabled through a licence key (although you'll probably get a better deal if you spec all the options you need initially). You can see a complete list of the software-enabled options in Table 2, overleaf.

There is also a detailed configuration guide which shows what options are available and what their respective software and hardware requirements are. You can view this online at siliconchip.com.au/link/ab1v

5G support

One of the fields where the N9918B will become very useful is in the design, testing, implementation and maintenance of 5G mobile networks. It appears the critical feature here is being able to do real-time analysis of signals with 100MHz of bandwidth.

While the existing 5G networks in Australia are running at a modest 3.5GHz, Telstra is trialling operation at millimetre-wave frequencies around 26GHz; perfectly within the capabilities of the N9918B. With the possibility of 5G using even higher frequencies, an external down-converter can be used to work with frequencies as high as 110GHz (!).

	N9917A	N9918B
Maximum Frequency	18GHz	26.5GHz
CAT/VNA Start Frequency	30kHz	30kHz
SA Start Frequency	5kHz	5kHz
VNA System Dynamic Range	100dB	> 114dB
Best Speed at 1001 Point, 1 Sweep	432µs/pt	171µs/pt
Output Power	-1dBm	8dBm
Trace Noise	0.004dB	0.001dB
Number of Built-In Ports	two	two
Instrument Type	Combination Analyser	Combination Analyser
Cable and Antenna Analyser	Yes - Standard	Yes - Standard
Spectrum Analyser	Yes - Optional	Yes - Optional
Vector Network Analyser	Yes - Optional	Yes - Optional
Standard Attenuator Range	30dB	40dB
Standard Attenuator Step	5dB	5dB
DANL @1GHz	-155dBm	-163dBm
Maximum Analysis Bandwidth	10MHz	100MHz
Phase Noise @1GHz (1MHz offset)	-113dBc/Hz	-124dBc/Hz
Phase Noise @1GHz (10kHz offset)	-111dBc/Hz	-117dBc/Hz
Phase Noise @1GHz (30kHz offset)	-108dBc/Hz	-115dBc/Hz
Spur Free Dynamic Range	> 105dB	> 104dB
TOI @1GHz (3rd Order Intercept)	+15dBm	+11dBm
Applications Available	Yes	Yes
Maximum Real-Time Bandwidth	10MHz	100MHz
Bandwidth Options	10MHz (standard)	10MHz, 40, 100MHz

Table 1: comparison between the (older) N1997A and the new N1998B Keysight Analysers.

One of the suggested options for the N9918B is a Phased Array Antenna which is designed to simulate the antennas used in 5G equipment. Thus, the N9918B is well-suited to being used in characterising and verifying the operation of 5G millimetre-wave networks.

Support for the Phased Array Antenna requires several dependent options to be installed too.

It appears that Telstra is in fact using Keysight equipment in their 5G trials. The photo overleaf shows a 5G work crew using a unit which looks suspiciously like the N9918B!

One of the other software options that is available is a GPS receiver, which requires a separate GPS antenna. This option can also be used to increase the frequency accuracy of the N9918B.

The apparent use for this is to be able to map 5G and other network coverage, including timestamps as well as location data. There is also an LTE (4G) addon, so existing networks can also be similarly analysed.

Other features

Apart from the 5G feature noted above, all the options

The right side of the unit with the three locking doors open. The LAN and USB device ports can used for remote control and offloading captured data. The SD card and USB device ports provide an alternative means for copying data from the analyser to a PC.

N9918B-010	Vector Network Analyser Time Domain
N9918B-030	Remote Control Capability
N9918B-208	USB Power Sensor Measurements Versus Frequency
N9918B-209	Extended Range Transmission Analysis (ERTA)
N9918B-210	Vector Network Analyser Transmission/Reflection
N9918B-211	Vector Network Analyser Full 2-port S-parameters
N9918B-212	Mixed-Mode S-Parameters
N9918B-215	TDR Cable Measurements
N9918B-233	Spectrum Analyser
N9918B-235	Pre-amplifier
N9918B-236	Interference Analyser and Spectrogram
N9918B-238	Spectrum Analyser Time Gating
N9918B-302	External USB Power Sensor Support
N9918B-307	GPS receiver
N9918B-308	Vector Voltmeter
N9918B-309	DC Bias Variable Voltage Source
N9918B-310	Built-in Power Meter
N9918B-312	Channel Scanner
N9918B-330	Pulse Measurements
N9918B-350	Real-time Spectrum Analyser (RTSA)
N9918B-351	I/Q Analyser (IQA)
N9918B-355	Analog Demodulation
N9918B-356	Noise Figure (NF)
N9918B-370	Over-the-Air (OTA) LTE FDD
N9918B-377	Over-the-Air (OTA) 5GTF
N9918B-360	Phased Array Antenna Control
N9918B-378	Over-the-Air (OTA) 5G NR
N9918B-352	Indoor and Outdoor Mapping
N9918B-358	EMF Measurements

Table 2 - the extensive N9918B options list

that are available on the N9918B are also available on the N9917A. So for the most part, it's the RF specifications that set it apart; the 5G support would simply not be possible without the improved bandwidth.

It's also worth noting that the 100MHz bandwidth is not mandatory. While not available as a post-purchase upgrade, there are variants which support either 10MHz, 40MHz or 100MHz bandwidth.

Conclusion

Other uses noted for the higher parts of the spectrum include satellite and radar technologies; not fields that many engineers even have access to, and unfortunately, not something that we can easily test. But we found in our earlier tests at lower frequencies that the FieldFox Analyser is a very capable unit that 'does what it says on the tin'. We have no reason to suspect that this latest version is any different.

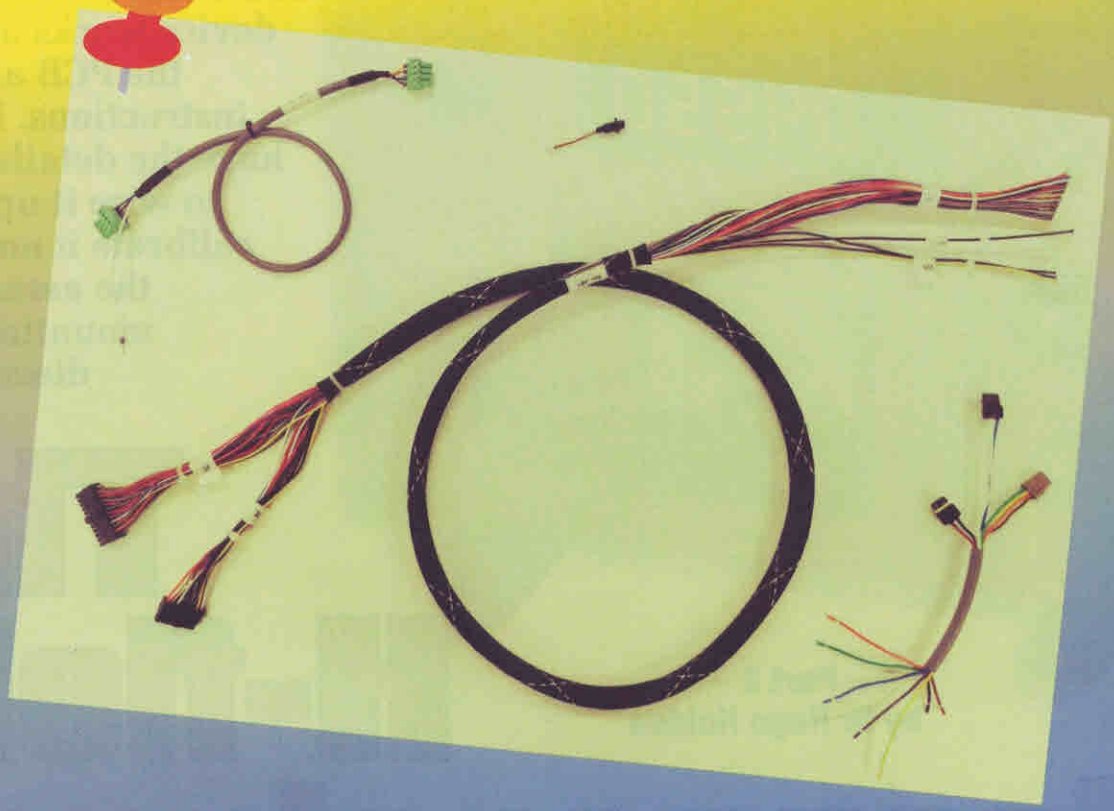
This unit, with the 100MHz bandwidth option, is clearly pitched as a tool for engineers working on 5G mobile phone networks; indeed, this feature is one of the first mentioned in the Technical Overview document. If that describes you, then we think you will quickly realise what you could do with such a device.

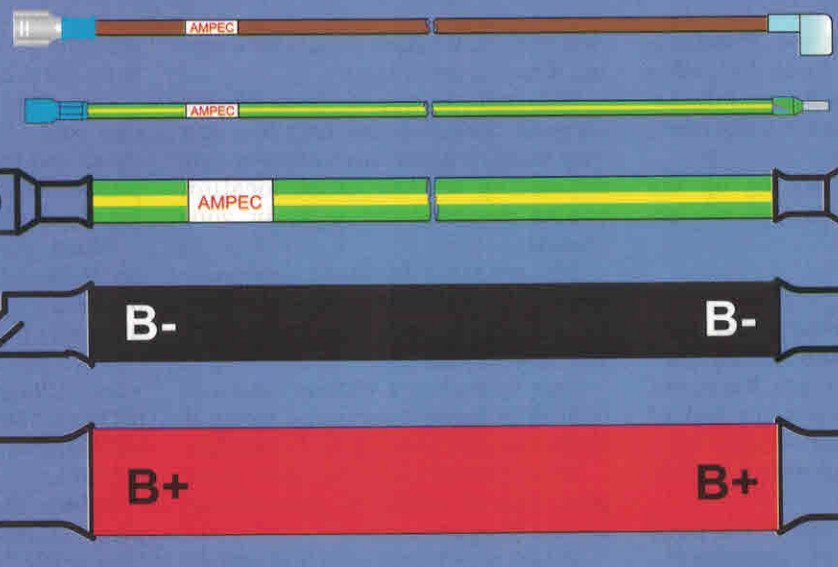
At the top of the analyser, the input/output N-connectors and SMA sockets for GPS antenna and reference input all have water-proof caps.

You can read more in Keysight's technical overview at siliconchip.com.au/link/ab1w or read through the complete product page at siliconchip.com.au/link/ab1x SC

Keysight has very clearly pitched the N9918B as an essential tool for working on the new 5G networks, and it appears that Telstra engineers are using it for precisely that purpose.

Wiring Harness Solutions





ampec TECHNOLOGIES

Ampec Technologies Pty Ltd

Tel: 02 8741 5000 Email: sales@ampec.com.au

Last month we described how this all-in-one AM radio test and alignment device works and gave the PCB assembly instructions. Now we have the details of how to wire it up, test it, calibrate it and finish the assembly by mounting it in a diecast case.

The H-field Transanalyser

Part 2 – by Dr Hugo Holden

If you're building the Transanalyser and have been following along, you should have a fully assembled PCB. But it is not quite ready to be powered up yet.

So let's get onto wiring up the remaining components that are not mounted on the PCB.

Chassis wiring

You can do the chassis wiring, plug everything together and test the unit before fitting it into its case. It may not perform brilliantly due to the lack of shielding, but if there is something wrong, it will be much easier to fix it at this stage.

But before you can test it, you need to wire up the DC socket, three chassis-mounting pots, the three input and output sockets and the LED frequency meter.

As the wiring is somewhat complicated, in addition to the following description, we have produced a wiring diagram (see Fig.5).

This includes approximate lengths for each cable run, but note that you may need to make some adjustments depending on the exact location you've mounted the parts in your chassis.

Also note that the terminal arrangements for VR4 & VR5 may be different depending on which exact parts you've purchased.

Start by cutting a 150mm length of light-duty figure-8 cable and solder it to the two live pins of the DC socket.

These sockets usually have three pins, one of which is open-circuit when a plug is inserted.

If you aren't sure which is which, plug in the plugpack, power it up and probe the pins with a DMM set to measure DC volts until you get a sensible reading. If the reading is positive, the red probe is on the + contact, whereas if it's negative, the black probe is on the + contact.

Once you've soldered the wire at that end, crimp and/or solder the other end to a pair of polarised plug pins and insert these into a two-way plastic shell.

When plugged into the DC input on the board, the wire from the + side of the DC socket must go to the side marked + on the PCB.

Next, cut three lengths of shielded wire: 120mm long for METER IN (CON1), 150mm long for 1kHz OUT (CON6) and 220mm long for RF OUT (CON7).

Solder these to the appropriate plugs, ie, BNC for RF OUT and either RCA or BNC (depending on your preference) for the other two. The shield braids go to the outer shields of the connectors.

Attach two-way header plugs to the other ends of these cables in a similar

manner as you did for the DC input. In each case, the inner conductor goes to the side that matches the + symbol on the PCB when plugged in, with the shield braid to the other side.

Make sure none of the shield braid wires are floating around so that they might short to something; if they are, cut them off.

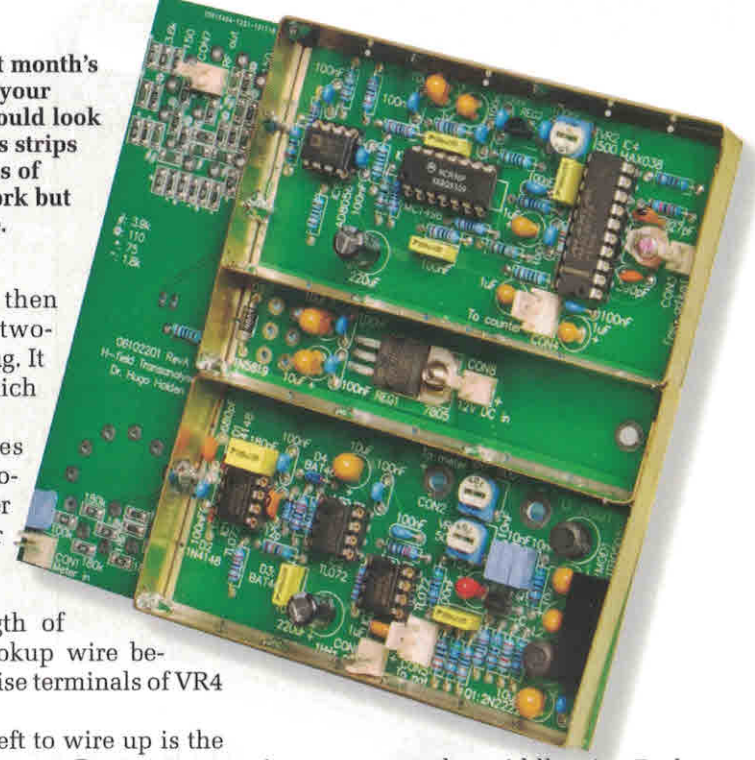
That just leaves the wiring for the three pots. You need a two-core (three conductor) shielded cable for the 1kHz output adjustment potentiometer; the type often used for stereo audio is fine. Cut a 120mm length and solder the shield braid to the anti-clockwise end of the 5kΩ potentiometer, VR6. The inner two conductors each go to one of the two other pins.

Crimp and/or solder pins to the three conductors at the other end, and insert them into the three-way plug shell.

Ensure that the wire going to the clockwise end of the potentiometer (viewed from the front of the pot) goes to the side marked with a + on header CON5. The shield braid goes to the opposite end of the plug, with the third wire (from the pot wiper) to the middle pin.

Solder wire off-cuts from the central wiper connection to the anti-clockwise end terminal on each of the two remaining pots, so that they become variable resistors which decrease in resistance when turned clockwise.

Then cut an 80mm length of figure-8 cable, and solder one end to a pair of pins which are then inserted into a two-way polarised plug. It doesn't matter which pin goes where.



Repeated from last month's issue, this is what your completed PCB should look like. We used brass strips for shielding; strips of tinplate should work but will rust over time.

Split the wires apart at the opposite end and solder them to the wiper terminals of VR4 and VR5. Then run a short length of medium-duty hookup wire between the clockwise terminals of VR4 and VR5.

The only part left to wire up is the LED frequency meter. Cut a 50mm length of shielded cable and a 100mm length of light-duty figure-8 cable. Crimp and/or solder these to pairs of pins and insert them into two-way plugs, either way around.

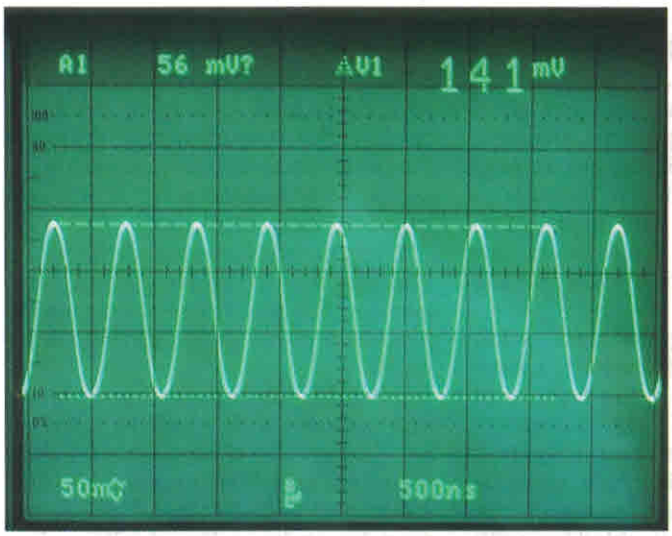
The shielded cable will go to the signal input on the back of the frequency meter, and the figure-8 cable to the power input.

These cables then meet at a single three-way plug to go to CON4 on the main PCB. The positive wire for the figure-8 power cable goes to the end marked + on the PCB, while the signal input goes to the middle pin. Both ground wires must be connected to the third pin, at the opposite end from the + symbol.

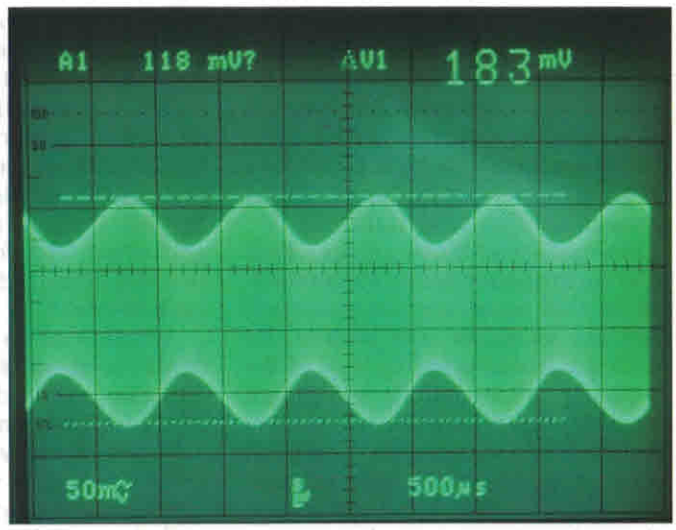
Testing and calibration

If you've used IC sockets, make sure all the ICs are plugged in now, with the correct orientation and in the right locations. Now is also a good time to pop the plastic cover off the analog meter and replace the 0-1mA scale inside with a 0-1mV (or similar) scale.

Temporarily attach the analog meter to the front of the PCB by removing



Scope1: this shows the RF output signal from CON7 when the 1kHz signal going into the modulator is disabled, resulting in a pure carrier wave. The frequency setting is around 1800kHz (ie, at the upper end of the adjustment range) and you can see that the sinewave is quite pure.



Scope2: the same signal as in Scope1 but the 1kHz signal has been re-enabled, so it is now 30% amplitude modulated. If the output of your unit does not look like this, adjust trimpot VR3 to get the correct modulation level.

Only four holes are required on the rear "panel" (which happens to be the base of the diecast case). Position is not particularly critical but the locations shown make sense.

the nuts from its two rear screw shafts, feeding these through the holes on the PCB marked "To meter", "CON2" and attaching the screws to these pads using a nut on either side (you need nuts just behind the meter to space it off so that it clears the solder joints under it).

Plug all these cables into the appropriate headers on the main PCB (see labels and the text above for an idea of which goes where), prop it up in a convenient location on a non-conducting surface and make sure none of the floating components and wires are shorting together.

Since you were careful to connect the plug wires correctly earlier, once you've made sure the right plugs go to the right headers on the board, all the connections should be right.

That just leaves the two plugs which go to the frequency meter. As the headers on that board are not polarised, they can go either way around. So check the labelling on the back of the frequency meter carefully and ensure that both plugs go into the right sockets (the shielded cable carries the signal) and that they have the right orientation, with the shield braid and ground wire connecting to ground.

Once that's sorted out, set rotary switch S1 on the board fully anti-clockwise and S2 (at top) fully clockwise. Adjust VC1 and VR1-VR3 to their halfway points and flip toggle switch S3 up.

Apply 12V power to the floating DC socket; nothing should happen since the power switch is off. Flip S3 and check that the frequency meter lights up. Adjusting floating potentiometers VR4 and VR5 should change the frequency reading.

Rotate VR4 and VR5 fully anti-clockwise and adjust VC1 to get a reading close to 205kHz on the frequency meter display. Now rotate both fully clockwise and check that the reading goes up to at least 1.8MHz.

For proper calibration, you need an oscilloscope or spectrum analyser. Connect this to the RF output on your instrument, set its input impedance to 75Ω (or use a 75Ω terminator) and adjust VR2 for a maximum carrier amplitude of 50mV RMS (141mV peak-to-peak).

Adjust VR3 to get a modulation depth of about 30%, which means a carrier amplitude at the troughs of 35mV RMS (100mV peak-to-peak).

Scope2 shows what the unit's output should look like with 30% modulation, while Scope1 shows the carrier with the modulator disabled (eg, with Q1's base shorted to its emitter).

Both grabs were taken with the loop connected, so the output is correctly loaded to give a 50mV RMS signal.

Next, connect a sinewave of known amplitude to the meter input, set S1 to select the correct range (fully anti-clockwise = 10V, one step clockwise = 1V etc) and then adjust VR1 to get the correct reading on the analog meter.

Final assembly

If you were able to complete the above calibration, then it seems that everything is working correctly and you can start preparing the case. Fig.6 shows the holes that need to be drilled and cut. You may need to enlarge the hole "A" at the far right of the case, depending on whether you're using a bezel for the LED and how big it is.

To make the rectangular cut-out for the frequency meter, drill a series of small holes inside the perimeter, join them up with a file, knock out the piece inside and then file the edges to shape. Don't worry about getting it perfect since we'll be fitting a bezel over the top later, but the meter needs to fit into the hole, and you don't want any huge chunks missing from around the edges.

You can make the large round hole for the analog meter in a similar manner, but it will be easier if you use a 44mm hole saw, which cost around $8 at most hardware stores. As the hole size is specified as 44.5mm, if you find your meter won't fit through, file around the edges until it does.

You also need to drill four holes in the rear of the case, close to the bottom edge. We haven't produced a drilling template as their exact locations are not critical.

Just make sure to drill them along a line parallel to the edge of the case, so it looks neat, and space the three on the left side apart evenly. Try to get the positions reasonably close to ours, as the cable lengths given earlier are based on those locations.

When finished, deburr all the holes. You can then consider painting and labelling the case. While not necessary, it gives a more professional-looking result.

After drilling and cutting my box, I first treated it with Bondrite, which is an Alodine-like etching agent. I then painted it with VHT spray paint from a can, and baked at 93°C in a home oven for an hour. You don't need to go to quite that much trouble; a few light coats from a can of decent spray paint suited to aluminium should give an acceptable result.

Using the Transanalyser with valve radios

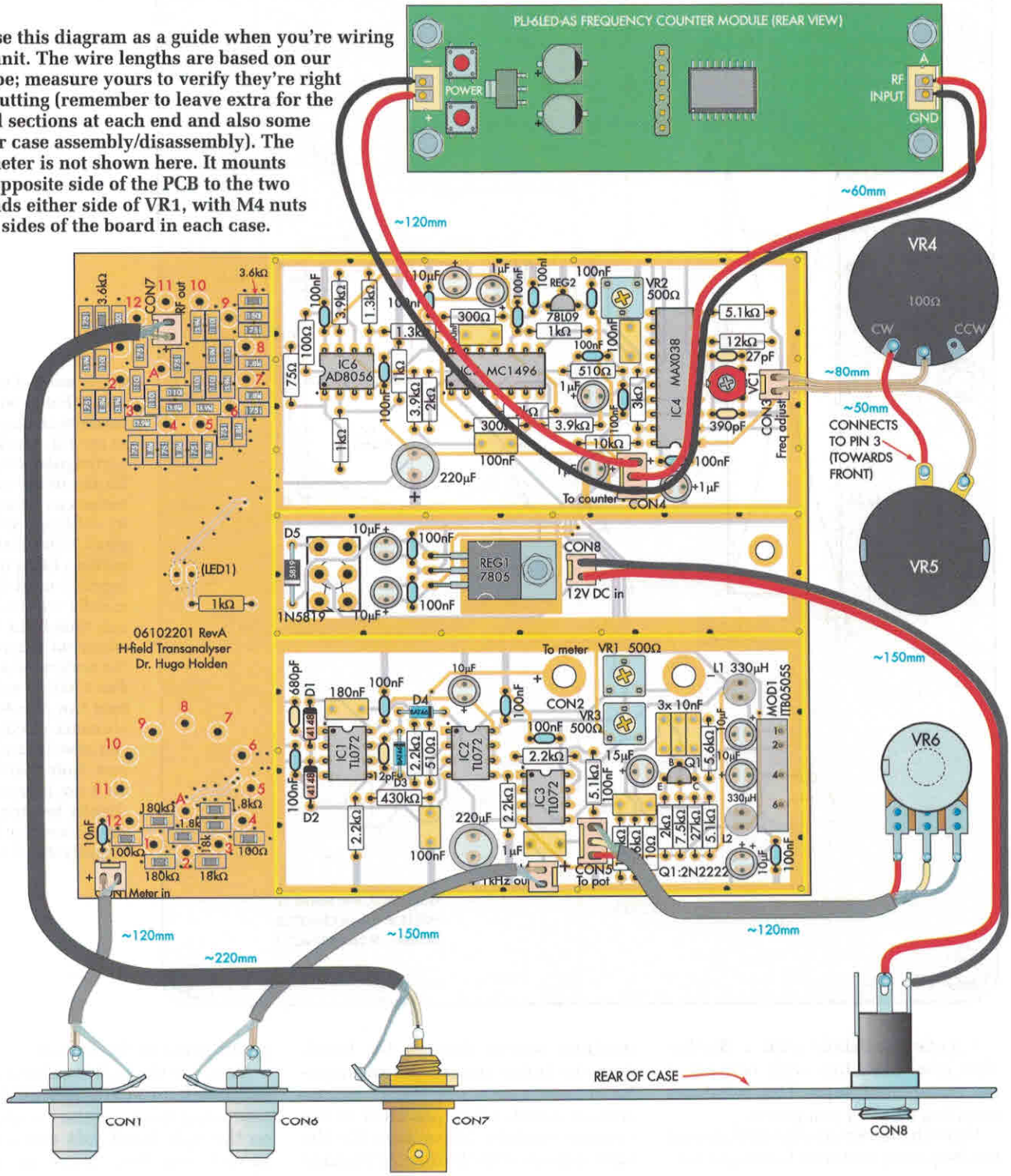
As noted in the text, the Transanalyser is intended mainly for use with transistor AM radios. But the 1kHz OUT and RF OUT terminals are provided so that it can also be used with valve-based gear.

If you are making any sort of direct connection to a valve radio with a hot chassis, you need to use an isolating transformer so that the chassis can be Earthed for making measurements and injecting signals.

Like most professional-grade RF generators, the Transanalyser's RF OUT is DC-coupled and has a low impedance (75Ω). So in many cases, you will need to insert a high-voltage series capacitor (say 10nF) to couple the signal into various points in a valve circuit. You may also need to include a series resistor to increase its effective output impedance to suit the circuitry being tested.

For example, add a 220Ω series resistor to couple the signal into a circuit expecing a ~300Ω source impedance.

Fig.5: use this diagram as a guide when you're wiring up the unit. The wire lengths are based on our prototype; measure yours to verify they're right before cutting (remember to leave extra for the stripped sections at each end and also some slack for case assembly/disassembly). The panel meter is not shown here. It mounts on the opposite side of the PCB to the two large pads either side of VR1, with M4 nuts on both sides of the board in each case.



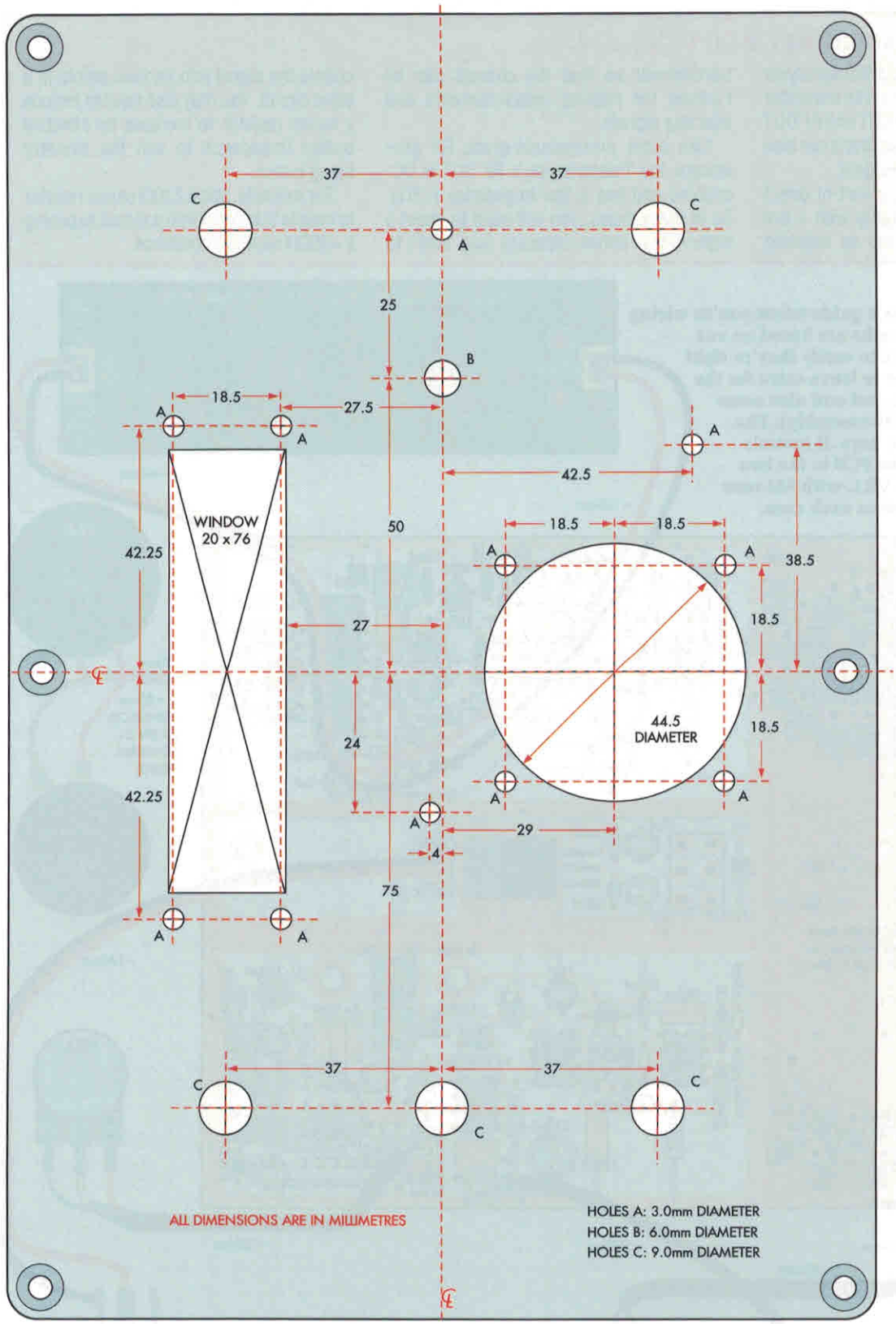
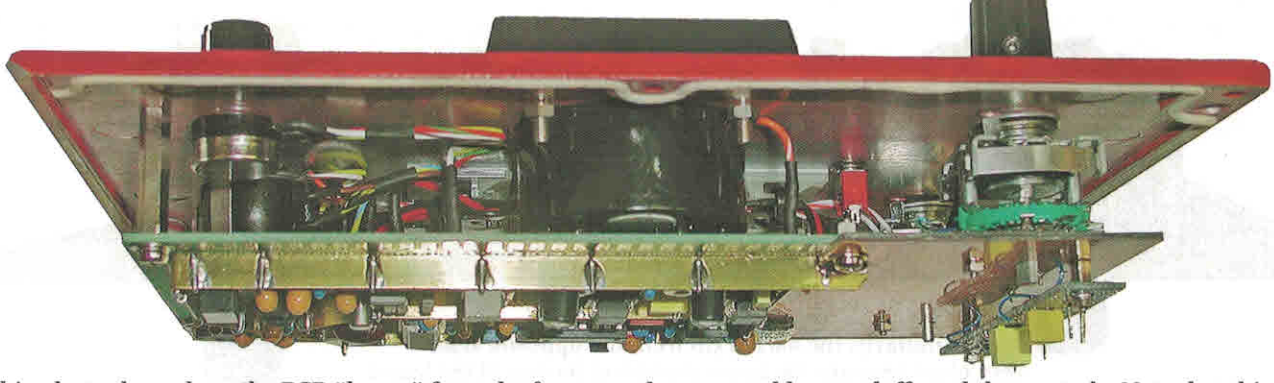


Fig.6: most of the holes that need to be made in the case are in the lid. The large rectangular cut-out for the frequency meter can be made by drilling a series of small holes inside the outline, filing them together until the middle section falls out, then filing the edges out to match the outline. If you don't have a suitable hole saw, the 44.5mm diameter circular hole can also be made this way. Note that this diagram is reproduced slightly less than same size – case size is actually 222 x 146mm.

I made the labels with a Brother tape label machine, with white text on transparent tape. Use whatever labelling method you prefer.

Once the labels are attached, mount the frequency meter by feeding in four machine screws through the bezel, then the holes around the rectangular cut-out, and screw them into the spacers which come pre-fitted to the counter module. Make sure it's the right way up, with the display decimal points towards the bottom.

Next, put the LED bezel into its hole and attach the PCB to the inside of the case using the two rotary switch nuts on the right-hand side and a tapped spacer and two machine screws



This photo shows how the PCB "hangs" from the front panel, supported by standoffs and the controls. Note that this is a photo of an early prototype board – the final PCB will look somewhat different.

through the PCB mounting hole and corresponding front panel hole at left.

We've specified a countersunk machine screw for the PCB mounting spacer through the front panel so that it sits flush, but you could use a panhead type if you don't want to countersink the hole.

Make sure the LED goes into its bezel as you bring the PCB up to the inside face of the case; note that you could get away without a bezel if you make the hole the same size as the LED lens.

The Transanalyser's case was mounted on 12mm thick tilted plastic feet attached with machine screws, so the front face adopts a 9° backwards tilt, to make it easier to view on the bench. If installing feet, do so now.

Then fit all the chassis-mounting components and wire them up to the main board, as you did before for testing. That includes the frequency meter. Leave the rear-panel components until last, as once you plug them in, access to the PCB will be limited. Then join the two halves of the case together using the supplied screws. Attach all the knobs to the various shafts and the main unit is finished.

The final step is to make up the cable that will be used to deliver the signal to the radio's antenna. You can see my arrangement in the photo on p91. I soldered the bare ends of the coax to a small piece of PCB material and attached two tiny thumb nut terminals. These allow the thin wire loop to be connected and disconnected as needed.

You will need to come up with a similar arrangement, although there are different ways you could achieve it. For example, the wire only needs to be disconnected at one end, and you could use a spring clip or some other wire connection device.

The loop should be made from thin wire-wrap wire or similar, so it can be threaded through a narrow space. This may be necessary where ferrite rods are mounted close to the radio case. Wire wrap wire works very well as it is delicate and easy to thread around a rod coil, easy to twist and doesn't put excessive force on the sometimes delicate ferrite rod coil wires nearby.

Using it

Disconnect the small loop from the end of the test lead and thread it once around the radio's ferrite rod antenna. The flying leads with alligator clips that lead to the Meter input circuit are connected across the radio's volume control outer terminals.

The loop has a very low reactance over the operating frequency range and acts like a dead short until the loop is placed around the ferrite rod. The resonant frequency of the tuned circuit on the rod then matches the applied frequency, and at that point, the loop's impedance increases.

The signal level at the volume control connection (detector output) is measured on the millivoltmeter in the Transanalyser. Why this is the preferred place to measure the radio's response and not at the speaker output is explained later.

Some calibration protocols and test instruments rely on monitoring the power level at the radio's speaker, with the RF input sensitivity quoted for say 50mW at the speaker. However, because there is a wide variation of speaker impedances, this sort of testing is fraught with difficulties and pitfalls.

Also, consider that depending on the volume control setting, the output stage could be driven into clipping, giving a false reading across the speaker. So I think it is better to test and analyse a transistor radio by monitoring the RMS voltage from its detector (or top leg of the volume control), rather than by a connection to the speaker.

The audio amplification stage of the radio can be checked separately by using the variable level 1kHz test tone provided by the Transanalyser. It is unlikely that the audio amplifier in small transistor radios would have to be checked at different frequencies, so the fixed 1kHz test tone should be adequate.

The transformers and speaker largely determine the frequency response in most vintage transistor radios, along with the capacitors in the output stage on later transistor radios. Any such electrolytic capacitors can be checked for ESR, leakage and capacitance easily, to verify that they are not having any adverse effect on the output frequency response due to ageing.

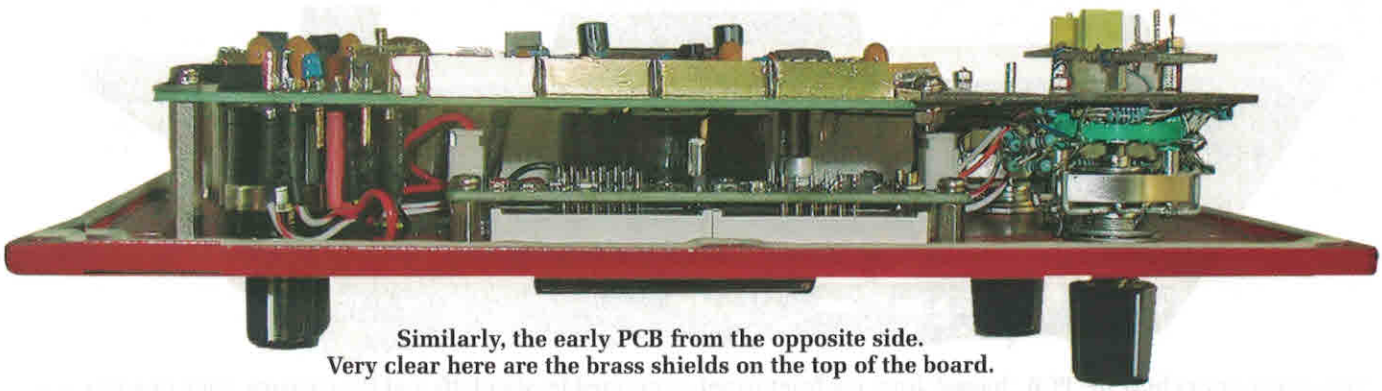
For radios with transformer-less audio amplifier designs (like the Hacker Sovereign and others), the only way to be 100% sure about the audio amplifier functionality is to do a full audio frequency sweep; however, a good listening test manipulating the bass and treble controls would show any significant fault.

The Transanalyser could be modified for its frequency synthesizer IC to produce an audio sweep, but in the interests of simplicity, I thought that to be unnecessary.

IF alignment

For IF alignment, you just need to set the Transanalyser to the correct intermediate frequency and feed the signal in via the loop as usual. The modulated IF signal will easily break through the mixer to the IF stages (even with the local oscillator running). This is preferable to injecting a 455kHz signal into the mixer output, as this alters the tuning.

Many transistor radios have a combined mixer-oscillator, so it is not possible to deactivate the oscillator without altering the operating conditions of the IF amplifier. In cases



Similarly, the early PCB from the opposite side. Very clear here are the brass shields on the top of the board.

where the radio has a separate oscillator transistor, it can be unplugged if it has a socket, or its base and emitter temporarily shorted out to deactivate it. A lower IF signal level will then be required to be fed into the antenna.

If the local oscillator is not (or cannot be) deactivated, it is best to have the radio tuned to the low end of the band for IF alignment. Regardless, use the weakest possible IF signal to peak the IF stages, but keep it above the noise floor by observing the effect on the millivoltmeter. Strong signals and AGC action can alter the IF tuning and make the tuning peaks more difficult to observe.

In addition, the test protocol for aligning IF stages (typically around 455kHz in most transistor radios) involves peaking them on the one centre frequency. The design of the IF transformers themselves determines the bandwidth.

This is one reason why a 'wobulator' or frequency sweep of the IF amplifiers in transistor radios has limited utility. They are not meant to be stagger-tuned to any specific bandpass characteristic (unlike the video IF stages in TV sets).

The IF bandpass response can be easily measured with the Transanalyser. You just adjust the Transanalyser's VFO up and down in frequency until the millivoltmeter reading drops to about 70% of its peak value, and subtract the two frequency measurements to determine the -3dB bandwidth.

Aligning transistor radios

Fig.7 shows the adjustments typically available in AM broadcast band transistor radios. Rarely, some radios (such as the NZ-made Pacemaker) have a three-gang capacitor and an additional radio frequency stage.

There are many variations, so it pays to check the manufacturer's alignment instructions. The information here is a general guide.

Twin-gang variable capacitor VC1 & VC2 are often 6-160pF and 5-65pF respectively, or similar value. If the gang values are the same, a padder capacitor is used to lower the overall value for the oscillator. VC1 tunes the antenna coil and TC1 trims the antenna circuit to set the high-end of the band to around 1200-1500kHz. A sliding coil on the ferrite rod is typically used to set the low end of the band to around 550-600kHz.

VC2 tunes the oscillator coil. A slug in the oscillator coil is used to set its lowest frequency to match the dial calibration, while TC2 sets the maximum oscillator frequency to match the upper dial calibration.

All IF transformer slugs are usually peaked on the specified centre frequency, typically 455kHz, although 465kHz is not uncommon. Very old transistor radios such as Regency TR-1 had 262.5kHz IFs. This is why the Transanalyser VFO output goes so low.

The oscillator is arranged to tune over a set of frequencies which are above the AM broadcast band by the intermediate frequency. So if the radio tunes stations from 550-1650kHz and the IF is 455kHz, the oscillator tunes over a range of (550+455)kHz to (1650+455)kHz, ie, 1005-2105kHz. The mixer then generates a difference signal at the same intermediate frequency for all stations.

Therefore, it is important that the tracking is correct. This represents the range of the frequencies tuned by the antenna coil on the ferrite rod versus the range of tuned frequencies selected by the oscillator frequency minus the IF frequency. The tracking can only ever be correct at three points; normally near the upper and lower ends of the band, and right in the middle.

Tracking errors occur on either side, but they are usually small, so the bandwidth of the IF stages is wide enough to let signals through that are slightly off due to these tracking errors.

Generally, the IF is aligned first to the correct centre frequency. Then a low-end signal at around 550kHz is used to adjust the oscillator slug; so the low end of the dial calibration is correct. If there is a padder capacitor, this is used instead of the oscillator coil slug, radios that use padder capacitors often have no adjustable slug in the oscillator coil.

Then a high-end signal around 1200-1500kHz (often specified in the alignment instructions) is used to adjust TC2 to make the dial calibration correct.

The above process is then repeated a few times, as one adjustment affects the other a little. This ensures that the IF and oscillator are correct and that the received frequencies are over the correct range and match the dial calibration as best possible.

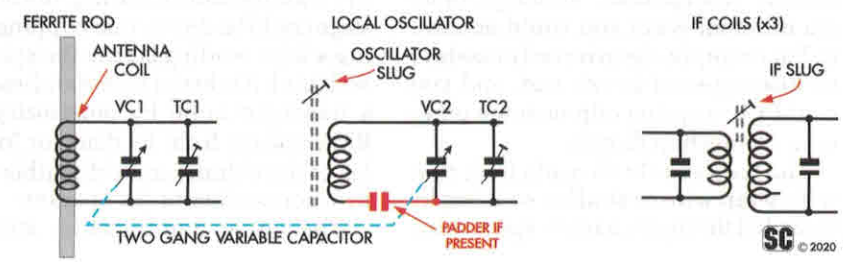


Fig.7: this shows the typical adjustments that are available in a transistor AM radio. VC1 & VC2 are the elements of the tuning gang. These are trimmed by TC1 and TC2 (and sometimes a moveable coil on the ferrite rod) to adjust the tuned frequencies at upper and lower ends of the dial, and to set the tracking. The IF coils usually have slugs which can be rotated to peak their response at or near the intermediate frequency.

TABLE 1: H-FIELD TRANSANALYSER TEST RESULTS – THREE RADIOS

LEVEL:		0dB	–10dB	–20dB	–30dB	–40dB	–50dB	–60dB	–70dB	–80dB
HACKER SOVEREIGN (2N2084)	mV OUTPUT	50	20	16	14	13	10	Meter fluctuations due to noise		
	SUBJECTIVE	N0	N0	N0	N0	N1	N3	N4	N5	N5
	CLIP RATIO = 5									
SONY TR-72	mV OUTPUT	120	160	165	100	70	Meter fluctuations due to noise			
	SUBJECTIVE	N0	N0	N0	N1	N2	N3	N4	N5	N5
	CLIP RATIO = 7.5									
NORDMENDE CLIPPER	mV OUTPUT	300	180	95	80	76	Meter fluctuations due to noise			
	SUBJECTIVE	N0	N0	N0	N1	N2	N3	N4	N5	N5
	CLIP RATIO = 7.5									

N0: No significant noise heard, just modulation
N1: Audible modulation >> Noise
N2: Audible Noise = Modulation
N3: Audible Noise >> Modulation
N4: Modulation just audible in Noise
N5: Noise heard only

Finally, the antenna circuit is peaked. TC1 is used at the high end. The low end can only be peaked by sliding the antenna coil on the ferrite rod. In many cases, it is completely sealed with wax and attempting to move it would damage it, so it is best to leave it alone and tolerate low end tracking errors.

Subjective performance tests

Listening to a radio receiver with a 1kHz modulated RF signal, I have found it that is very easy to subjectively grade the noise into five categories without too much ambiguity. I label them as follows:

- N0 – no significant noise heard, just the loud and clear demodulated signal
- N1 – modulated signal level is greater than the background noise
- N2 – the modulated signal and noise levels seem equal
- N3 – noise is dominant, but the modulated signal is still audible
- N4 – the modulated signal is barely audible in heavy noise
- N5 – only noise is heard.

I tested three radios, and the results are shown in Table 1. Note how the Hacker Sovereign (on the AM broadcast band) has relatively low detected audio voltage levels, but as it has much more gain in its audio amplifier stages, the subjective results are better than the other two radios listed.

This radio had been re-populated with 2N2084 transistors, as the original failed from tin whiskers.

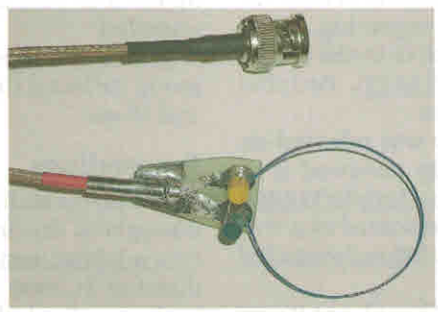
Clearly, in the noise department, the 2N2084 transistors are superior to those used in the 1956 TR-72 or the OC44/45 or similar used in the Nordmende Clipper.

The "Clip Ratio" numbers given are the ratio between the output of the detector with a strong antenna signal and the voltage at the wiper of the volume control pot just on the edge of clipping.

Another way of looking at this is that the higher the Clip Ratio, the weaker a radio station can be and still give you full volume at the speaker.

This number is a good way of doing a quick 'health check' of a radio even if you know little about it.

If you get a figure in the range of 4-10, that indicates that the radio's front end is more or less healthy and providing enough signal to the audio stages for it to be useful even with weaker (eg, more distant) stations.



This small PCB, with a 75 terminating resistor, has screw terminals allowing the loop to be disconnected and threaded around the ferrite rod.

The numerator for the Clip Ratio can be read right off the Transanalyser's voltmeter with its output attenuator set to 0dB, but the denominator is a bit more tricky.

You can measure this by connecting the Transanalyser's 1kHz audio output between the radio's volume control pot wiper and ground, with the volume control set to mid position so that the control itself does not load the applied signal.

You then adjust the 1kHz output level and measure its amplitude at the onset of clipping. This is easily determined without an oscilloscope by the sound from the speaker. The 'soft' sound of the sinewave suddenly becomes 'sharp' with a 'zinging' sound at clipping, due to the high-frequency harmonics created.

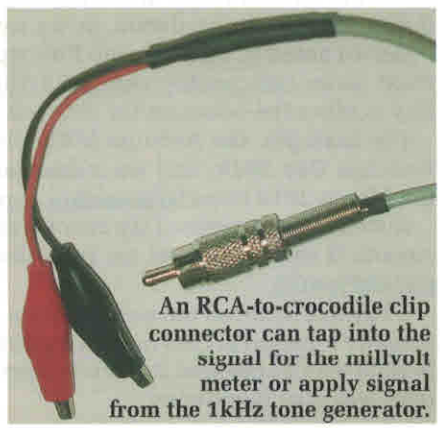
Other notes

In general, when feeding the radio a test signal from the Transanalyser (or any source for alignment purposes), the audio signal (recovered modulation) should be enough to hear clearly above the noise, but not so high as to induce significant AGC action. The AGC action minimises the visible peaks on the output meter, and AGC also alters the tuning.

For the three radios I tested, a good level was with the Transanalyser's attenuator setting at either -30dB or -40dB.

It is also possible to use the Transanalyser to determine the signal level where the radio's AGC becomes active.

If the radio (or the Transanalyser's) tuning frequency is manually adjusted across the tuned carrier, the millivoltmeter momentarily passes to a higher value before settling to a lower one, which is easy to see on the analog meter. This is due to the time constant of the radio's AGC filter. SC



An RCA-to-crocodile clip connector can tap into the signal for the millvolt meter or apply signal from the 1kHz tone generator.

Arduino Day 2020 at the Jaycar maker hub

SILICON CHIP's Editor Nicholas Vinen and Technical Team Member Tim Blythman ventured out to Jaycar's maker hub at Central Park Mall on March 21st, to celebrate Arduino Day with fellow Arduino enthusiasts and help with various Arduino-based projects.

March 2020 was shaping up to be a great month for makers. While March 21st was originally promoted as a global day by the people behind Arduino, there was not much activity in terms of new Arduino software or hardware, as we were expecting.

As we noted in our Arduino Retrospective in the March 2020 issue (siliconchip.com.au/Article/12575), Arduino Day is often the occasion for new releases.

For example, the Arduino MKR Vidor was released on Arduino Day 2018, and we subsequently reviewed it in the March 2019 issue (siliconchip.com.au/Article/11448).

Instead, the Arduino Day event was presented as a live stream; it can be viewed on YouTube at https://youtu.be/u93BhPnooZc

They did mention the new Portenta H7 board, but it was actually released at CES in January 2020. The Arduino CLI (which we also covered in our retrospective) was also mentioned.

by Tim Blythman

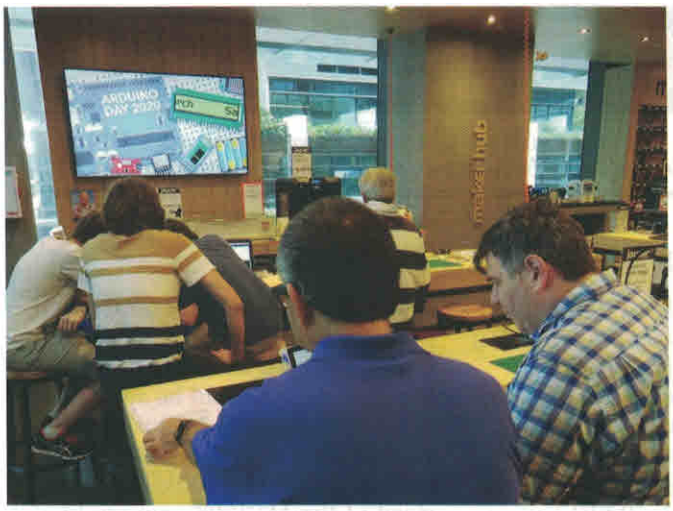
With the shadow of COVID-19 hanging around us, we weren't sure what to expect. Happily, everyone was keen for Arduino Day to go ahead and SILICON CHIP staff, Jaycar's maker hub staff and assorted Arduino fans of many ages attended.

With elbow taps instead of handshakes, a small but eager group gathered (but not too tightly) to share their projects and ideas.

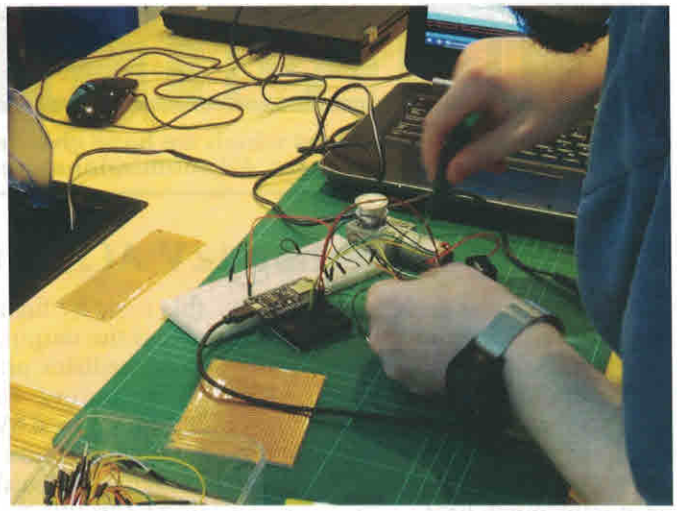
Proceedings

The Jaycar staff, led by Darren, ran a series of workshops throughout the day, starting with the Snake Game project (www.jaycar.com.au/snake-game), which is built using their Cat XC3900 Arduino Learning Kit. A few enthusiastic beginners (including some quite young and some not so young) took part in this.

We had set up a display featuring a number of our Arduino-based projects,



Between workshops, small groups gathered to share ideas and get help. The maker hub is well laid out for both roles, with shelves of Arduino products nearby for that last-minute add-on. Photo by Dan Malone.



We're still impressed by the little tips and tricks that people come up with. Using a development board that is too wide for a breadboard can be frustrating; the trick is to use two breadboards side by side! Photo by Dan Malone.

and we had a few curious individuals looking at them and asking questions.

For the most part, those attending were just starting out with Arduino; most had a good idea of what they wanted to do, but were not sure how. Some had well-developed projects and were simply stuck and looking for advice. Others were tentatively interested in Arduino and just wanted to ask some questions and get comfortable with the idea of working on hardware.

One common refrain we heard was that they were experienced programmers but had no idea how to build hardware. When we showed them how it could be done, by plugging Arduino modules together, they unanimously commented that it was a lot easier than they were expecting!

The overall vibe was one of knowledge, curiosity and sharing. The projects we helped with included a game controller, a device for remote operation of curtain blinds and an environmental monitor. A few were looking to add a colour touchscreen display to their project, but had run into problems.

One of our demonstration projects was our 3.5in LCD Breakout Board for Arduino (www.siliconchip.com.au/Article/11629), which is very simple hardware-wise, but looks very impressive when showing off the graphics that are possible.

As we have often found, a colour touchscreen display is a very useful thing to have, but can also be a great deal of work due to apparently identical hardware having vastly different software requirements.

We ended up helping two attendees get their displays up and running. One of them commented that he had been trying to get it to work for around six months, and was delighted when it did!

Uno repairs

As promised, we brought along some spare parts to assist with a hands-on version of our *"Fixing a Busted Uno"* article from the March 2020 issue (siliconchip.com.au/Article/12582). To their credit, none of our attendees had any damaged Unos, so we demonstrated on a unit that Jaycar had in their store, which turned out to need a new ATmega328 chip.

We replaced the SMD ICs regardless, to demonstrate how it is done. As we removed and reinstalled the chips, those present were able to view the activity through a USB microscope attached to a large monitor.

Thank yous

We want to thank Darren, Dan and the other Jaycar staff for hosting us. It's great to see the maker hub being used for hands-on activities.

The ability of customers to see actual working projects being built before their eyes (rather than merely being static and hanging on a hook) shows the value of the maker hub concept.

As things start to return to normal, we hope to see Jaycar's regularly scheduled workshops (which were operating at many stores, not just the Broadway maker hub) continue.

Who knows, you might even see us again in the future!

Darren is the resident Arduino expert at the maker hub, and is patient and knowledgeable. Here he presents one of the many workshop sessions that ran during Arduino Day. Photo by Dan Malone.

SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Efficiently converting 12V AC/DC to 24V, 5V and 3.3V

This supply was designed to power a circuit with motors and solenoids that require 24V, plus digital and analog control circuitry needing 5V and 3.3V rails. It delivers all three regulated rails from a single 12V input without wasting a lot of energy or producing much heat.

It is built around three integrated switchmode regulator ICs, IC1-IC3, operating as DC/DC converters. IC1 operates as a boost converter while IC2 and IC3 operate in buck (step-down) mode.

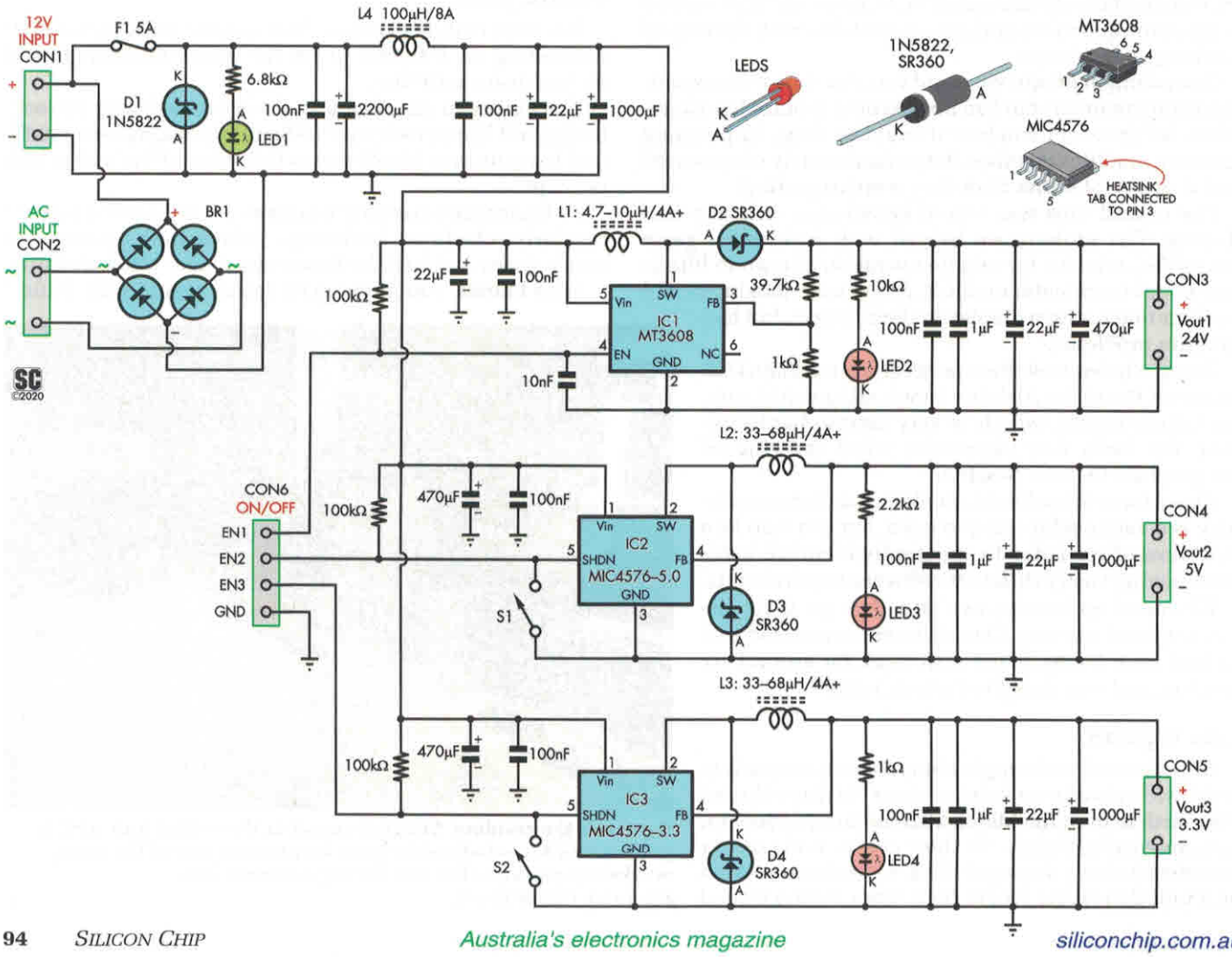
IC1 is a high-efficiency step-up (boost) converter chip which switches at 1.2MHz. This reduces the size of the required inductor and capacitors. IC1's output voltage is adjustable up to 28V; this is set by the ratio of the resistors across the output, with the tap going to its feedback pin (pin 3).

The output voltage is (R_{UPPER} ÷ R_{LOWER} + 1) × 0.6V, where 0.6V is the internal reference voltage of MT3608. Plugging in the values used here gives us 24.42V ([39.7 + 1] × 0.6V).

The output current from this IC is up to 2A, while the internal switch has around 4A current limit (necessary since in a switchmode circuit, the peak current is somewhat higher than the average current). One advantage of this MT3608 IC is that, unlike many others, it does not need an external RC compensation network, which often has to be tweaked to suit each application.

The MT3608 has an on/off (enable) pin which would be useful if the circuit is powered from a 12V battery, as the 24V output could be switched off when it isn't needed. This is done by pulling pin 4 of IC1 low; it is normally pulled high by the 100kΩ resistor. Instead of the MT3608, you could also use an HM1549 IC as it is functionally equivalent.

In operation, pin 1 (switch) of IC1 is pulled low with a varying duty cycle at 1.2MHz. When low, current flows from the 12V supply through L1, charging up its magnetic field. When IC1 switches off the drive to pin 1, the collapsing magnetic field in L1 causes that pin voltage to shoot up and schottky



diode D2 is forward-biased, charging up the output capacitors.

The feedback voltage at the FB pin is used to adjust the duty cycle of the switch pin, to keep the output close to the desired 24V.

To keep the circuit simple, step-down regulators IC2 and IC3 have fixed output voltages, so they do not need external resistors to set the output voltage, nor do they require any compensation components for stability.

These chips switch at 200kHz, and they operate a bit differently from IC1. When the internal switch is on, current can flow from the V_{IN} pin (pin 1) through to the switch pin (pin 2) and then onto inductor L2/L3 and the output capacitors. When the internal switch is off, the voltage at the switch pins shoots negative, so diode D3/D4 is forward biased and this supplies current to L2/L3 during the off-time.

Inductor L2/L3 and the output capacitors form LC low-pass filters to convert the square-wave-like waveform from the switch pin into a much smoother output voltage with only a little ripple. As with IC1, the duty cycle of this switching action is varied to maintain the desired output voltage.

Like IC1, IC2 & IC3 have shutdown pins (pin 5), which can be used to disable that rail. But these work in the opposite manner; when pulled up by the 100kΩ resistor, the regulator is shut down. The pin must be pulled down to enable it. This can be done via pins EN2 and EN3 of CON6, or using switches S1 and S2.

The incoming 12V supply passes through a CLC π filter to prevent external ripple feeding through the switchmode regulators, and also to stop switchmode noise going out via the power lead. If the supply is 12V AC, this is fed into CON2 and converted to around 16V DC by bridge rectifier BR1, to power the rest of the circuit.

Note that IC1, IC2 and IC3 require some heatsinking. The MT3608 is only available in SMD packages, so it needs to be connected to a large enough copper area to dissipate its internally generated heat (see its data sheet for details). The MIC4576 is available in SMD and TO-220 packages; for the TO-220 package, a small flag heatsink is adequate. If using the SMD version, the same comments about copper area apply.

Petre Petrov,
Sofia, Bulgaria ($80).

Simple I²C serial bus snooper

I²C is a very convenient and powerful communications protocol; it's wonderful when it works, but difficult to debug when it does not. An oscilloscope is of limited use unless it's one of the more expensive models with I²C decoding, and even then, doesn't always help that much.

What you really need is a continuous printout of bytes being transmitted over the bus, with reports of ack, nack, start, stop and restart conditions. This simple circuit based on a PIC18F4620, along with the supplied software, does just that.

The requirement to send three bytes to the serial port for every I²C word received means that you need a relatively powerful processor and plenty of RAM.

The PIC18F4620 can run at 8MIPS using its on-chip 8MHz oscillator with the 4x PLL option enabled. It has 4KB of RAM, but the software uses only 2KB to simplify the code.

Received words are stored in a circular buffer and then fed to the serial port when it is free. With data coming in at 100kHz and leaving at 115,200 baud, the buffer will fill after about 900 I²C words are received.

This is not a serious limitation, as the buffer empties very quickly during any pauses. A facility is provided to stop acquisition after 256 words, which is very useful if data is being repeated.

The hardware is just the processor, a serial-to-USB converter, a pull-up resistor for IC1's MCLR (RESET) pin and a couple of bypass capacitors.

If you don't have a PIC18F4620, you can also use a PIC18F2525, PIC18F2620 or PIC18F4525.

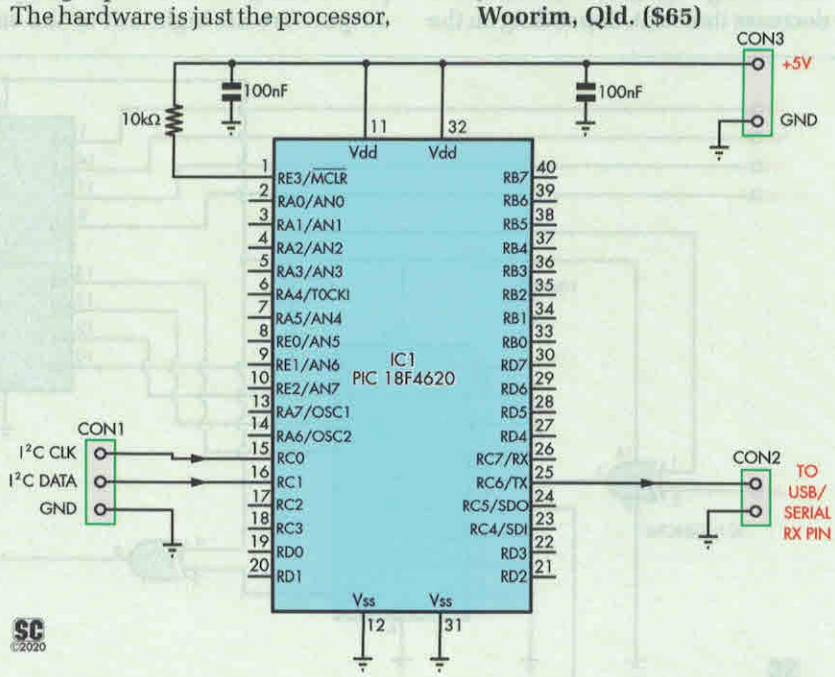
The software works with an I²C bus running at 100kHz but it may have problems at 400kHz; I was unable to test that. Obviously, the buffer will fill more quickly at the higher bus speed. 400kHz could be accommodated by using a faster processor or with additional hardware.

The software prints an "S" character when it detects a start event, "P" for a stop event, "R" for reset, "A" for ack and "N" for nack. It prints a two-digit hexadecimal string for each byte between the start and stop events, and a carriage return after the stop event, so that each separate I²C transaction appears on a different line of the terminal.

One benefit to using this circuit is that it lets you find and fix inefficiencies in I²C communications.

For example, I used it to monitor the messages between a micro, LCD screen and real-time clock chip and I found many redundant or repeated commands, and separate commands which could be combined into one, allowing me to change the software to communicate much more efficiently.

John Nestor,
Woorim, Qld. ($65)



Frequency divider with a 50% duty cycle output

This circuit produces an output which has a frequency that is an integral fraction of the input signal, and maintains the 50% duty cycle present at its input, as long as it receives a square wave. Otherwise, it produces a divided frequency signal with a duty cycle closer to 50% than the one at its input.

I tried to keep the circuit as simple as possible, while also allowing frequency division by any integer value with no circuit changes. It is not particularly sensitive to the signal frequency either.

One advantage of a divider with a 50% duty cycle output is that it is relatively easy to filter that output to give a sinewave.

Scientific papers have been written on frequency dividers that give square waves. In general, complex circuits are proposed in those publications and could be implemented within an integrated circuit. Unlike my circuit, those circuits are difficult to build with a handful of ICs.

Fig.1 shows my circuit. The signal is fed into one of the inputs of XOR gate IC1a. The interconnection of IC1a and counter IC2 makes IC2 count on the rising as well as the falling edges of the incoming signal. This is because each time the input signal changes state, the two inputs of IC1a have opposite values, so its output is high.

That rising edge makes IC2 increase or decrease its count, depending on the state of pin 10. Output Q0 (pin 6) of IC2 (the least significant bit) then reaches the same state as the input signal, so the output of IC1a goes low. As a result, upon each rising and falling edge of the incoming signal, a very short pulse appears at the clock input of IC2.

The length of this pulse depends on the delay of both IC1a and IC2; the faster these integrated circuits are, the shorter the pulse will be.

The outputs of counter IC2 (Q0-Q3) feed one of the input nibbles (four bits) of digital comparator IC3 (A0-A3). The other input nibble is the division ratio N, described as a binary value. In other words, N0-N3 are held high or low to determine the desired division ratio.

The count direction of IC2 depends on the state of output Q1 of flip-flop IC4a (pin 5). If on power-up Q1 is low, IC2 will count downwards on each edge of the incoming signal, until the outputs (Q3-Q0) of IC2 are all low. IC2 will then bring its $\overline{TC}$ output low. IC1b acts as an inverter so that this results in input CP1 of IC4a (pin 3) going high, bringing its Q1 output high.

IC2 will then count upwards on the rising and falling edges of the incoming signal. When the count reaches the value N, output pin 7 of IC3 (a<b) will go low. This resets IC4a, so output Q1 goes low and IC2 starts counting down again.

Note that when N=15, the $\overline{TC}$ output of IC2 goes low when its Q0-Q3 outputs are all high, but at the same time, pin 7 of IC3 goes low, and as it drives the reset line of IC4a, this takes priority over its pin 3 being high, so the circuit still works correctly in the N=15 case.

The complementary outputs of IC4a are the outputs of the circuit. For an even value of N, both will always have a duty cycle of 50%. For an odd value of N, if the input signal has a duty cycle of 50%, the outputs also will; if the input duty cycle is different from 50%, the output duty cycle can be calculated as: [2 × (input duty cycle) + N - 1] ÷ 2N.

For example, if N = 5 and DC_{IN} = 0.4 (40%), then DC_{OUT} = 0.48 (48%). This is closer to 50% than the 40% or 60% values obtainable with simpler circuits based on a counter that counts either rising or falling edges.

Scope 1 shows the output of the prototype (upper trace) and input (lower trace) when an 8.46MHz, 50% duty cycle signal is applied with N=5. The result is a 1.692MHz square wave.

For division ratios greater than 15, any number of 74HCT4516 counters and 78HC85 comparators can be cascaded. Other comparators, such as the 8-bit 74HC688, can be used instead.

Also, for some fixed division ratios, the circuit can be simplified. Fig.2 shows a divide-by-5 circuit where the comparator and the D flip-flop have been replaced by a NAND gate (IC5a) and a NAND-based latch (IC5b and IC5c). In this circuit, a divide by 2.5

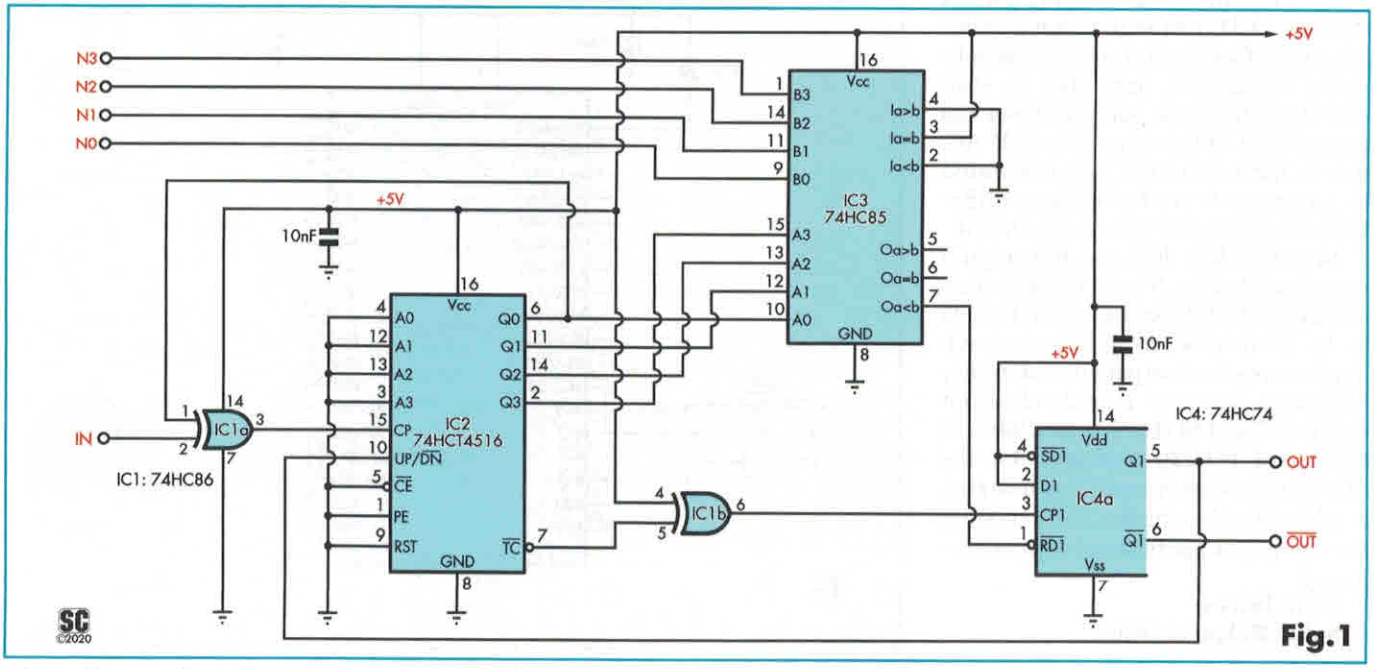


Fig.1

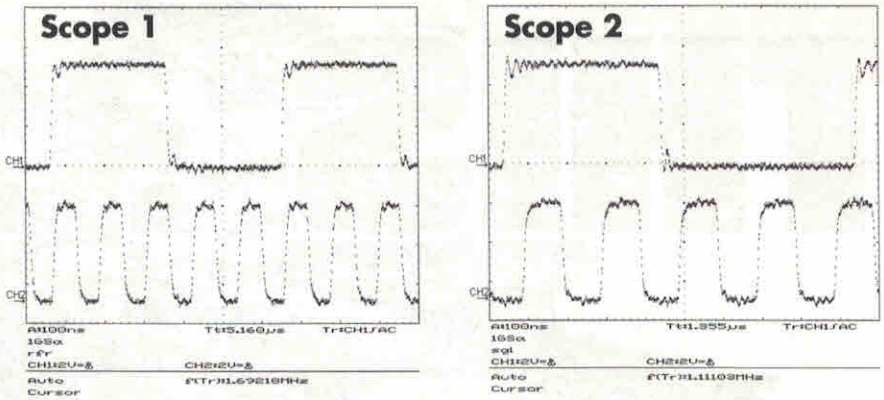
output is available too, although its duty cycle will not be 50%.

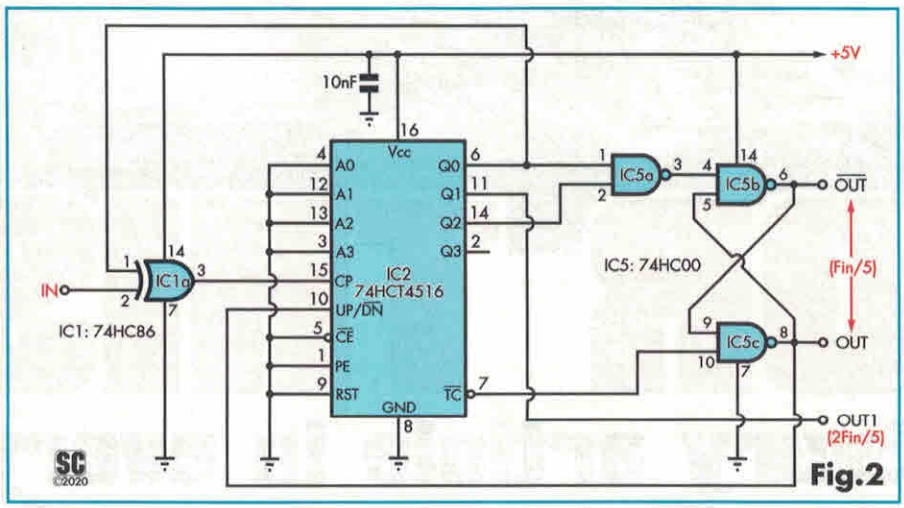
With a few additions to the circuit of Fig.1, it can be made to divide by fractional values between 3 ÷ 2 (1.5) and 29 ÷ 2 (14.5). However, again the output duty cycle will not be 50%. Fig.3 shows the modified circuit. The other half of dual flip-flop IC4 (IC4b) is added, plus another XOR gate (IC1c). When pin 13 of IC4b is low, the division ratio is the integer N; if it is high, the division ratio is N - ½.

With pin 13 low, flip-flop IC4b is held in reset with its Q2 output low, so IC1c works as a buffer. Therefore, the circuit functions identically to the one shown in Fig.1. But if pin 13 of IC4b is high, it functions as a T flip-flop, toggling each time it receives a rising edge at its clock input, which is connected to the Q1 output of IC4a.

Thus, when IC2 activates its $\overline{TC}$ output and the count direction changes, input pin 13 of IC1c is toggled, and this adds another edge to the signal at pin 2 of IC1a. So that edge is counted by IC2, and IC2 needs one fewer pulse to reach the maximum or minimum value. As a result, the input frequency will be divided by N - ½ instead of N.

Scope 2 is a scope grab showing the circuit set to divide a 5MHz square wave (bottom) by a factor of 4.5. The result (top trace) is a 1.111 MHz signal with less than 50% duty cycle, obtained at the Q1 output of IC4a. With fractional division, if the input signal duty cycle is not 50%, the output signal will suffer from jitter.

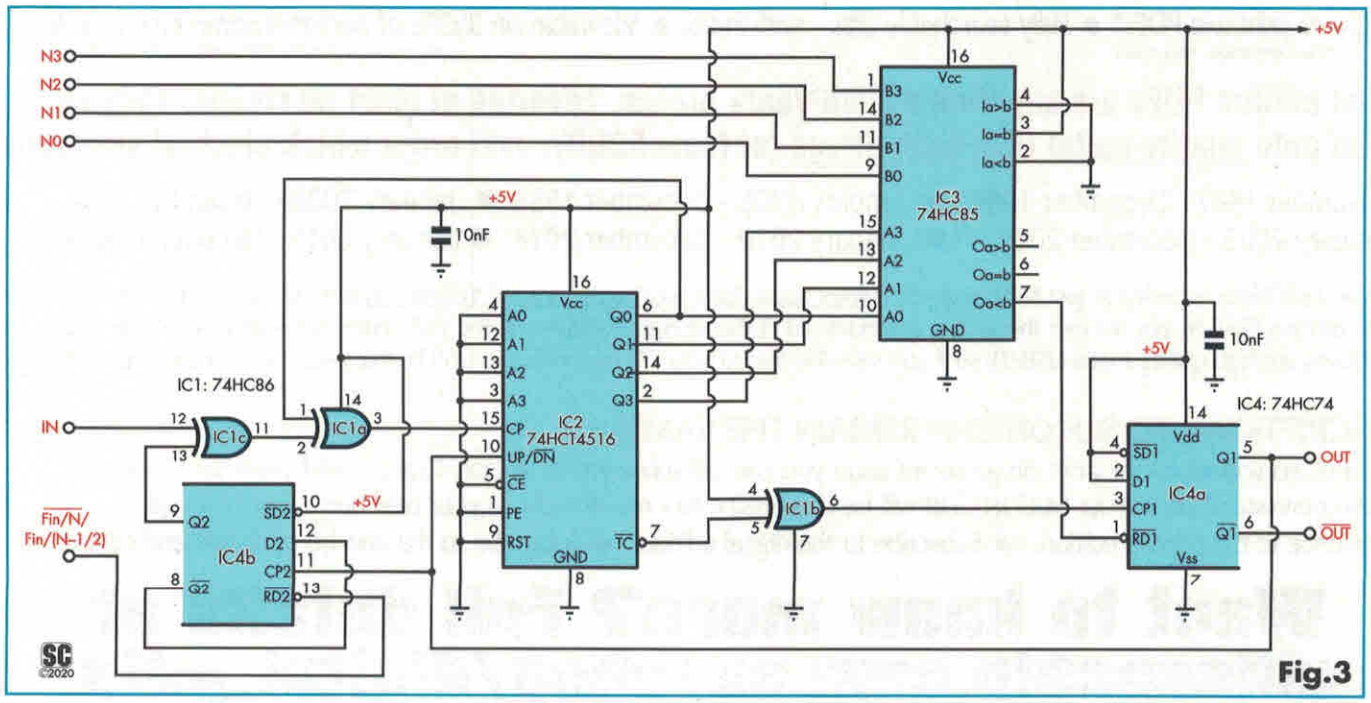




Using the devices shown and dividing by an integral value, the circuits will operate up to about 9MHz. For fractional division, the circuit of Fig.3 will work up to around 5MHz. Other logic families can be used instead; if slow CMOS (4000B-series) devices are used, the maximum frequency will be lower.

Faster devices can also be used. I experimented by replacing the 74HCT4516 counter with a 74AC169 (which has a different pinout), and the maximum frequencies increased to 16MHz for integral divisors and 8MHz when dividing by N - ½.

Ariel G. Benvenuto,
Parana, Argentina. ($100)



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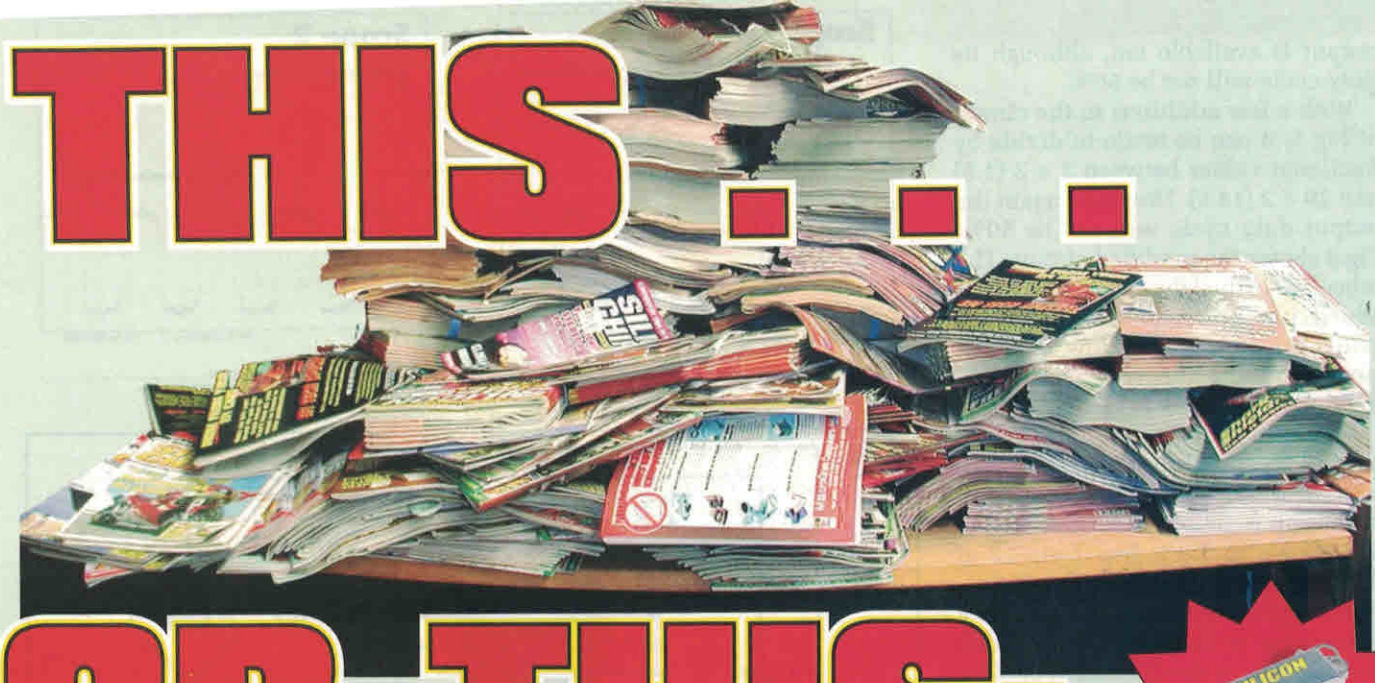

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VINTAGE RADIO

Tecnico 1952 Model 1259A
The Pacemaker

By Associate Professor Graham Parslow

Australian radios do not come much quirkier than this one. In this set, the entire dial flips up during use, exposing the speaker grille, which is normally hidden behind it. Unfortunately, this is a case of 'style over substance', as the sound quality suffers from this unusual configuration.

The standard case for portables of the early 50s was a fabric-coated timber box with a flip-up or down panel that protected the dial and speaker. So this design is quite a deviation from the norm. Unfortunately, the relatively small area revealed when the dial is flipped up limits the useful size of the speaker that can be mounted behind it.

In this case, it is a Rola 5C 5-inch speaker that provides inferior performance to other contemporary portables, which often incorporated 6in or 8in speakers.

This set was available with other case colours, including red and grey. Most buyers were likely to choose a Pacemaker for style, rather than performance. Despite this, they went all-out with the circuit design, including fitting it with an RF amplification stage. It has both battery and mains power supply options. A visually identical battery-only model was also available, designated 1259B.

The back panel of the radio clicks into place without retaining screws, so it is easy to move the mains power cord in and out of storage.

My first impression on seeing the chassis from the rear is that everything is sturdy and comparable to most other portables of the time. A minor exception is the slim mains transformer, but it does not need to deliver high power, and there is limited space available for it.

Features

In 1952, most old stock of full-size octal valves had been used up, and sets using all miniature valves were becoming the norm. In this case, five 7-pin miniature valves have been used for a conventional lineup of functions for a superhet radio with RF amplification.

The circuit for this set is therefore significantly different from the 1946 model 651 "Aristocrat" and 1950 model 1050 "Fortress" sets from the same manufacturer that we described previously. Those articles were featured in our February 2020 (siliconchip.com.au/Article/12350) & April 2020 (siliconchip.com.au/Article/13817) issues, respectively.

One innovative aspect of this radio is the use of a selenium rectifier stack, rather than a rectifier valve, which uses five selenium elements to produce DC from the mains transformer secondary. Selenium diodes could not withstand much more than 25V peak inverse voltage, so this stack of five can deliver 112V to C27 (50µF, 150V).

The voltage dropping resistor R19 (1.5kΩ, 1W) lowers the HT to 94V. Toggle switch S2, at the rear of the chassis, provides an easy means to switch between battery and mains. In this case, the battery is a dual-output type in a single package (Eveready type

753), incorporating a 9V "A" battery and a 90V "B" battery.

The filaments of these one-series valves are all carefully manufactured so that they draw 50mA at 1.5V, allowing them to be connected in series.

That also applies to the 3V4 audio output pentode valve, which has two 1.5V filaments in series, so it can be driven by either 3V between pins 1 & 7, or 1.5V with pins 1 and 7 joined, plus a connection to pin 5 (the centre tap).

So there are four valves in this set with 1.5V filaments and one with a 3V filament, giving 9V total (4 × 1.5V + 3V). The 3V4 is the output valve, so it needs higher electron emission from the filament to provide the meagre 250mW of audio output; hence, its filament consumes twice the power of the others, operating at the same current but with twice the voltage.

When it comes to listening, it is decibels rather than watts that determines the acceptability of the listening experience, so the 3V4 is perfectly adequate for this radio.

Construction

As indicated on the circuit diagram, the loop antenna that forms the primary tuning coil is located behind the dial scale. The brass spring clip used to connect an external aerial is mounted on the side of the chassis adjacent to the "A" stencilled on the rear panel of the chassis. The other end of the chassis has a similar earth clip adjacent to the "E" marked on the chassis.

The location of the loop antenna, elevated above the metal components within the case, means that there is no shielding blocking reception from any direction. In practice, the antenna by itself is adequate for receiving local stations, partly due to the extra amplification provided by the first 1T4 pentode valve, operating as an RF amplifier.

The mechanism driving the flip-up lid is relatively simple, as illustrated in Fig.2 for removing the chassis from the cabinet. The dial string is driven by a second drum attached to the tuning capacitor shaft. The string passes through a hole in the right-hand pivot point of the dial. The flexibility of the string easily copes with the rotation of the lid through 180° without overly affecting its tension.

Disassembly may seem like a fiendish task, but it is surprisingly easy. Removing two chassis clamping screws at the rear, then removing the knobs allows the chassis to slide out. The dial must be kept at 90° as the chassis is removed, so it passes smoothly through a slot in the case above the speaker grille.

The case is most likely made from PVC, not Bakelite.

Circuit details

The circuit is shown in Fig.1. It's a relatively conventional superhet with an RF preamplifier. This preamplifier stage means that a three-gang tuning capacitor is needed, with one gang for tuning the aerial circuit, one for the local oscillator and one for the RF preamplifier. This ensures that only signals around the tuned station are amplified.

The local oscillator (L4, L5 and C13) produces the appropriate difference frequency to feed to the oscillator grid (marked OG) on the 1R5. L4 provides positive feedback to the local oscillator to sustain oscillation. The 455kHz IF signal passes from the 1R5 mixer to the first IF transformer, for IF amplification by the second 1T4.

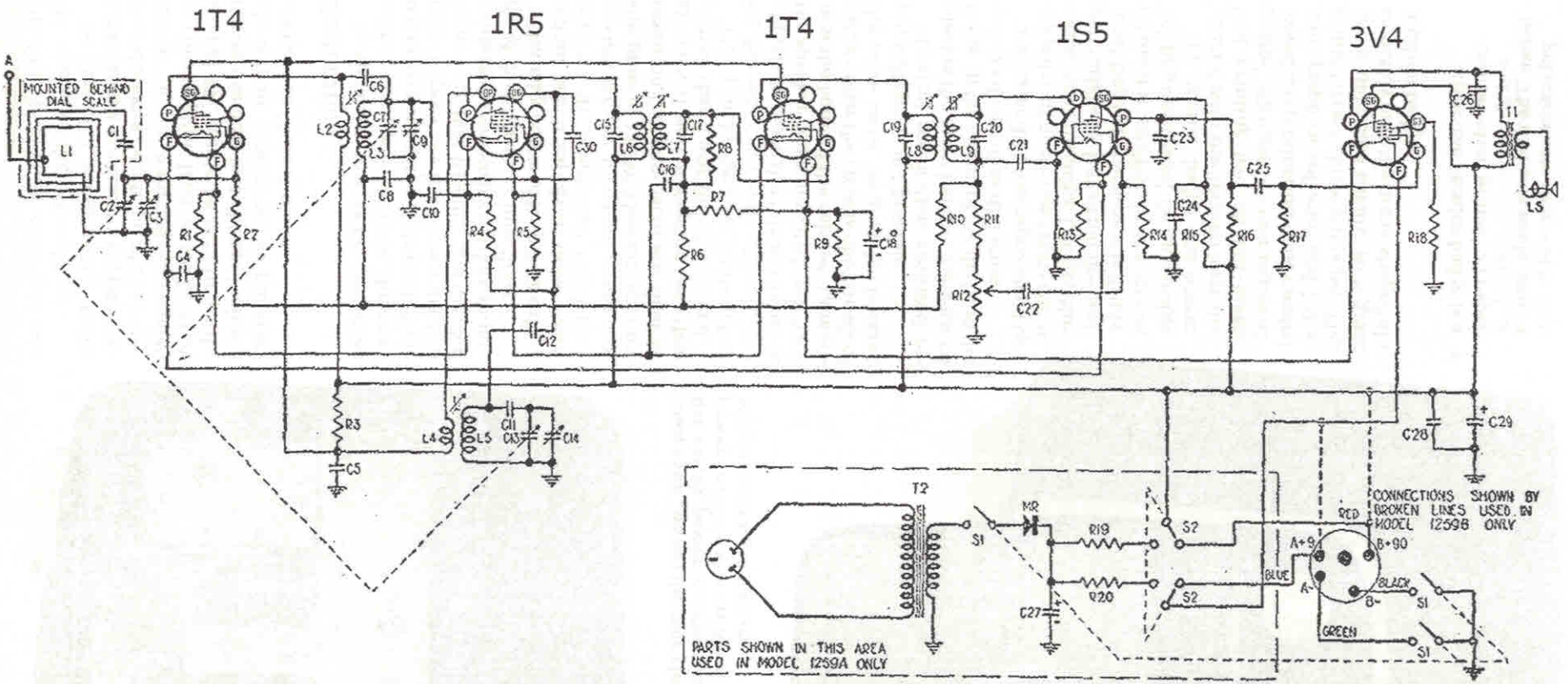
The second IF transformer is coupled to the single diode in the 1S5 diode-pentode valve to demodulate the signal and also to generate the automatic gain control (AGC) voltage. This feeds back to the first two stages to lower gain for high strength signals via R10 (1MΩ).

R12 (500kΩ) is the volume control potentiometer that passes the signal to the 1S5 audio preamplifier pentode grid. There is no tone control on this radio.

The 3V4 output pentode grid gets audio from the 1S5 via 10nF capacitor C25. Grid bias is generated via the series filament connections. The 3V4 filaments are connected at the top of the 9V supply stack, and this is a directly-heated valve, so pin 5 is also the cathode connection. Its grid is DC biased to ground, so the grid is negative relative to the cathode.

While using a directly-heated valve can complicate the design, it has the advantage of a near-instant turn on without a significant warm-up period. The selenium solid-state rectifier facilitates quick operation on mains; other contemporary mains/battery receivers that used a 6X4 valve rectifier with an indirectly heated cathode took some time for the HT supply to come up after switch-on.

When powered from the mains, the filament current is derived from the full HT using series resistor R20, specified as 2kΩ, 5W. In practice, R20 is two 4kΩ resistors in parallel, both rated at 5W. This combination drops



R1	1500 ohm ½ Watt	C1	.005 uF ± 5% Mica
R2	1 Megohm ½ Watt	C2	12-450 uuF Gang Section
R3	10,000 ohm 1 Watt	C3	3-30 uuF Trimmer
R4	.1 Megohm ½ Watt	C4	.1 uF 200V Paper
R5	2000 ohm ½ Watt	C5	.1. uF 200V Paper
R6	2 Megohm ½ Watt	C6	4 uuF Mica
R7	2 Megohm ½ Watt	C7	12-450 uuF Gang Section
R8	.5 Megohm ½ Watt	C8	.05 uF 200V Paper
R9	2000 ohm ½ Watt	C9	3-30 uuF Trimmer
R10	1 Megohm ½ Watt	C10	.1 uF 200V Paper
R11	.1 Megohm ½ Watt	C11	120 uuF ± 5% Mica
R12	.5 Megohm Volume Control	C12	50 uuF Mica
R13	500 ohm ½ Watt	C13	12-450 uuF Gang Section
R14	10 Megohm ½ Watt	C14	3-30 uuF Trimmer
R15	3 Megohm 1 Watt	C15	Part of I.F. Transformer
R16	.5 Megohm ½ Watt	C16	.05 uF 200V Paper
R17	1 Megohm ½ Watt	C17	Part of I.F. Transformer
R18	2000 ohm ½ Watt	C18	250 uF 12V Electrolytic*
R19	1500 ohm 1 Watt	C19	Part of I.F. Transformer
R20	2000 ohm 5 Watt	C20	Part of I.F. Transformer

C21	100 uuF Mica	L1	Loop Aerial
C22	500 uuF Mica	L2 & L3	Coil, R.F.
C23	100 uuF Mica	L4 & L5	Coil, Oscillator
C24	.1uF 200V Paper	L6 & L7	I.F. Transformer, 1st
C25	.01 uF 600 V Paper	L8 & L9	I.F. Transformer, 2nd
C26	.005 uF 600V Paper		
C27	50 uF 150V Electrolytic	T1	Speaker
C28	.1 uF 200V Paper	T2	Power Transformer
C29	50 uF 150V Electrolytic		
C30	1 uuF Mica	S1	Lid Switch Assy.
		S2	A.C./Batt. (OAK Type 78)

Fig.1: the Tecnico 1259A came in two versions: a B variant which could only be powered via a battery (an Eveready 753); and the A variant which also included a mains plug and the necessary circuitry to allow the 240V AC 50/60Hz mains to supply the required 90V HT and 9V LT. Another difference is that in the 1259B, C18 (a 250µF 12V electrolytic capacitor connected to the filament of pentode 1T4) is instead rated at 25µF 40V.

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103V; the dissipation will be just over 5W, shared by the two resistors.

Its operating mains power totals 11W. From a manufacturing perspective, the extra cost to provide a separate 9V supply, reducing mains power consumption (and waste heat) by around 5W, would be hard to justify. Power use does not change with audio volume because the output stage operates in Class-A mode.

Restoration

Fortunately, this radio presented with no component failures. However, before powering it up, I cleaned all the pins. Experience has shown me that many portables like this one develop oxide creep, which breaks the continuity of the filament connections.

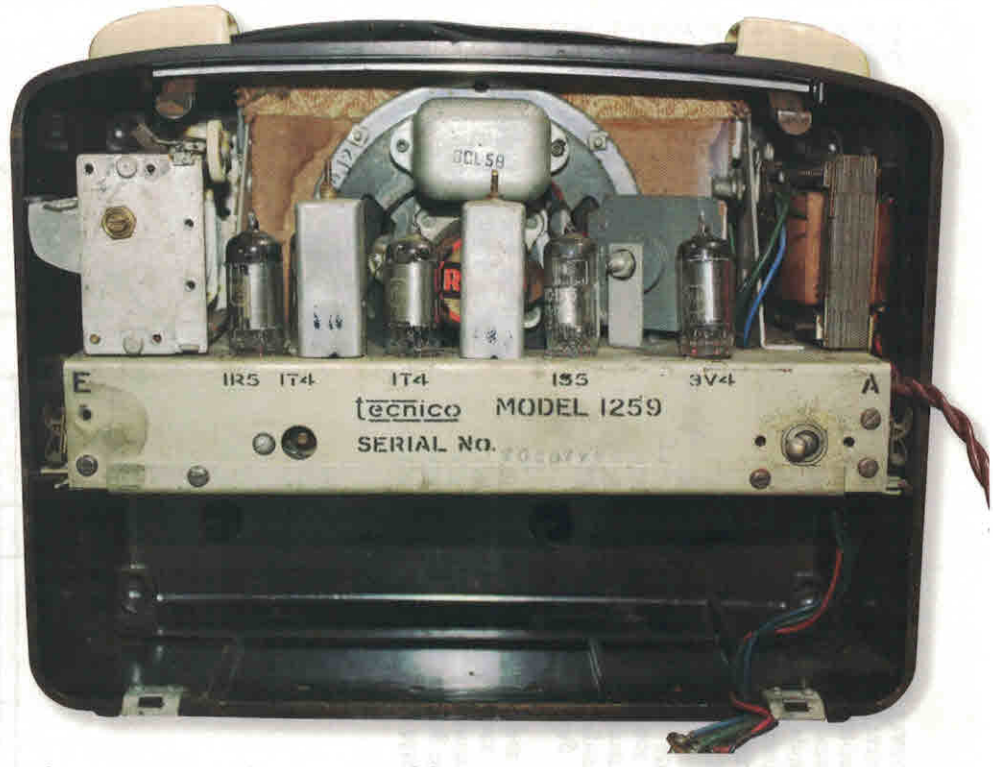
I initially powered it up from a dual-output bench supply. It drew 50mA from the 9V supply and 13mA from the 90V supply, for a total power consumption of 1.62W. These are spot-on, based on the manufacturers' data, so all seemed well. Reception tests then proved that it was fully functional.

That's lucky because fault-finding on this radio would be difficult. The chassis is unusually thin as a result of the speaker being mounted well back into the body of the cabinet. Components under the chassis obscure all of the valve bases. So directly checking pin voltages is not possible.

Physical restoration required replacing the carry handle, the Tecnico badge in the centre of the dial and the yellowed cellulose dial cover.

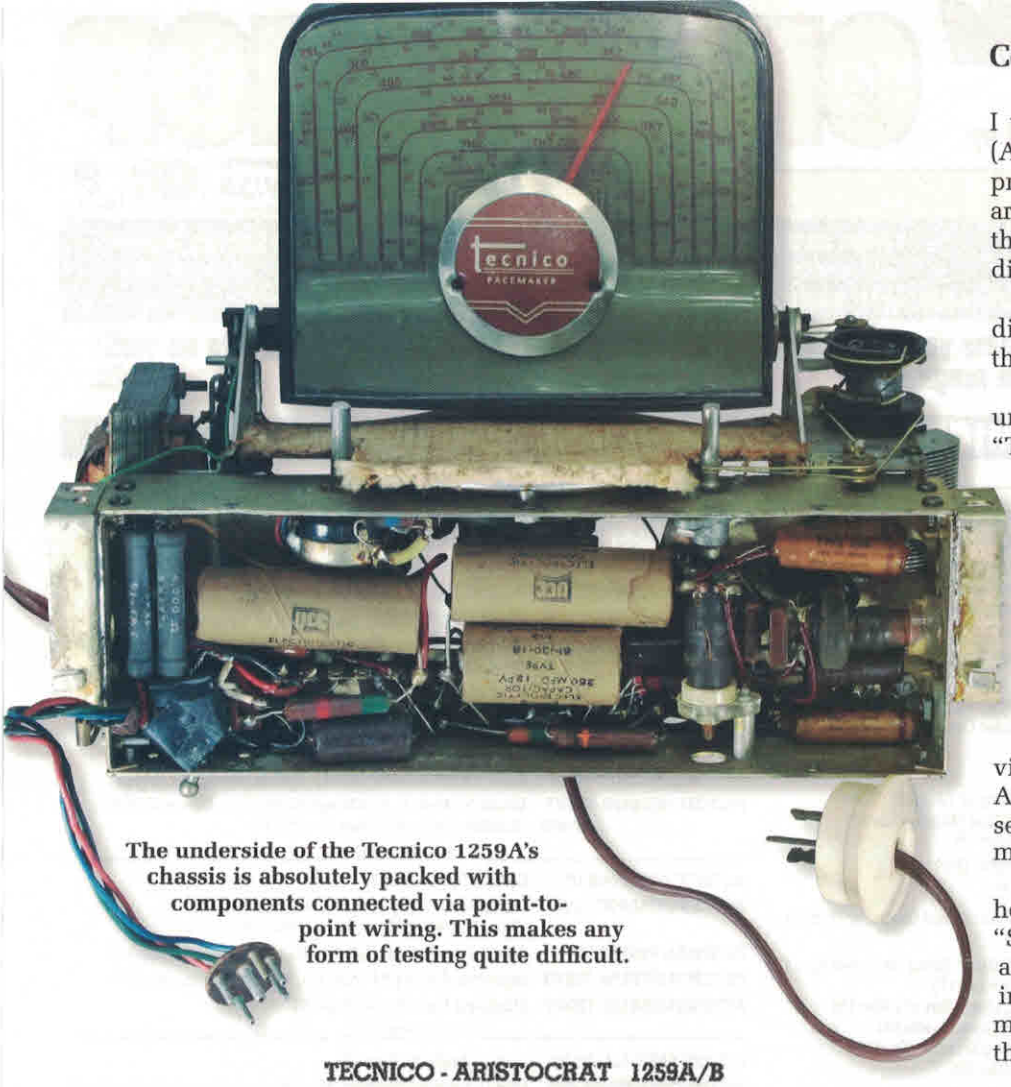
The clear dial was reproduced using polycarbonate sheet that I cut to shape using tin snips. Luckily, the polycarbonate did not require heat moulding to fit because it is firmly retained in position by the screws holding the central Tecnico badge.

The original badge was screen-printed with the Tecnico logo, and that printing had all but disappeared. Pictures of other radios allowed a reproduction to be created with graphics software and I then printed it on lightweight paper. This paper deformed evenly, so it glued smoothly onto the dome-shaped aluminium badge.



Above you can see the rear view of the Tecnico 1259A's chassis showing the five valves, power transformer, variable capacitor and Rola 5-inch speaker; the power switch is also visible at lower right. One nice feature, is that all valves are marked on the chassis.

Right: the Tecnico badge is a reproduction printed on paper and glued onto an aluminium badge. The dial was made using a polycarbonate sheet cut to size.



The underside of the Tecnico 1259A's chassis is absolutely packed with components connected via point-to-point wiring. This makes any form of testing quite difficult.

TECNICO - ARISTOCRAT 1259A/B

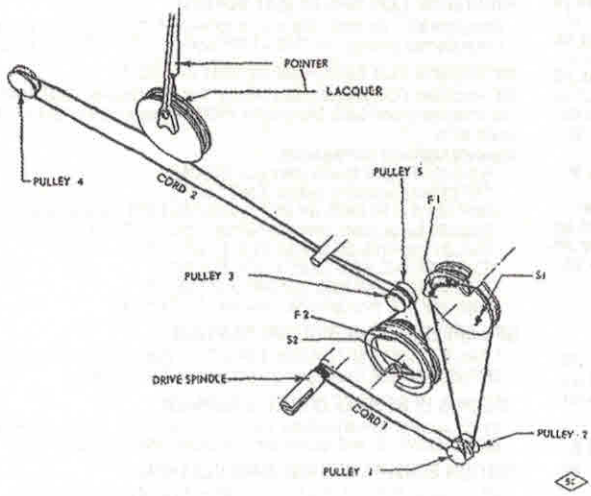
METHOD OF REMOVING CHASSIS FROM CABINET

Remove the cabinet back by placing a finger in the centre hole and pulling back. The hooked feet at the bottom of the lid can then be lifted clear of the holes in the base of the cabinet. Withdraw the plug from the battery and remove the battery.

Pull the control knobs off their spindles.

The chassis is secured to the front of the cabinet by two screws which pass through a bracket at each end of the chassis. Remové these screws and raise the front lid of the cabinet to the horizontal position. The chassis and lid assembly can then be withdrawn from the back of the cabinet.

WARNING: Do not force the lid back beyond the vertical position whilst out of the cabinet, otherwise the lid may be damaged.



Conclusion

As mentioned in passing earlier, I wrote up the Tecnico models 651 (Aristocrat) and 1050 (The Fortress) in previous Vintage Radio articles. This article on the Pacemaker completes the trilogy, covering the stand-out radio icons made by Tecnico.

So who designed this unusual radio? It is most likely to be Zenith in the USA.

A Zenith advertisement in the Saturday Evening Post of 1948 proclaims "The new Zenith Pacemaker is one great forward step in radionic engineering and modern styling".

The Pacemaker then appeared in New Zealand, manufactured by Collier and Beale in Wellington (see the book "Radio Days" by Peter Sheridan and Ritchie Singer, p247).

Tecnico had associations with Collier and Beale as they had previously made and marketed Tecnico Aristocrat radios. Consequently, it seems that the right to use the Pacemaker design passed to Tecnico.

The cabinet of the radio featured here is moulded with the attribution "Seco mould CAT. No. 700-1 C&B Ltd" and it seems likely that the cases were imported from the USA (other Tecnico models in my collection do not have this attribution).

These are my own surmises, and they may be in error; any corrections from readers who know more would be welcome. SC

The Zenith radio in question which has a near identical design to the Tecnico 1259A with the exception of the dial.

◀ Fig.2 (left): a diagram showing the dial cord arrangement and explaining how to remove the chassis.

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Choice of oven for Solder Reflow

I'm interested in building your DIY Reflow Oven (April-May 2020; siliconchip.com.au/Series/343). Big W has a Russell Hobbs toaster oven that is smaller than Kmart's, and desirable for boards 200 x 200mm or smaller. It is a dual element type with mechanical controls but only rated at 1150W and has a thermostat that goes to 230°C. Would this work? It's on special for $49 at the moment.

The Big W unit has two glass element heaters, top and bottom, while the Kmart oven has four standard elements. The volume of the heated area of the Big W unit would be less than half of the one from Kmart. I presume that heating time would be similar, if not shorter than the Kmart unit. The elements on the Russell Hobbs oven are shielded by a metal plate that has plenty of airflow.

Also, is your design suitable for soldering boards with SMDs on both sides? Usually, for this type of board, the components are glued before flow soldering, although I suspect surface tension would hold smaller, lighter items on both sides. I currently use a reflow gun to mount components.

I suppose it would be possible to shield one side of a board while reflowing the other if component drop was a problem on the underside. For larger TQFP packages, soldering with a hot air gun is not ideal; I have managed so far, but your unit would be better. (C. S., Fraser, ACT)

● Phil Prosser responds: I understand the attraction to a neat little oven. Not having had the chance to test it, all I can do is give you the best pointers I can. The challenge this oven might face is being able to heat rapidly enough. It is tantalizingly close though... some serious equivocation follows! I will try to give you the information you need to decide for yourself.

The controller will cope with this reasonably well, as in the development of the code, the case of an underpowered oven was considered. If the oven is slow to heat, the controller will stay in the final "heat" mode until the oven hits the reflow temperature. Once it hits the end temperature, it shuts off the heater. But how long will it take to reach it?

I have a lingering concern that this will result in protracted final reflow heating time. If this is too long, it could damage ICs. To be honest, the 1500W unit we used was, in our opinion, 'just up to the job'.

If the size is a critical parameter, then it may be worth just trying it out, and if the oven does not have the oomph required, go back to plan B and get a higher-power unit.

You can test this by simply switching the oven on and watching how long it takes to heat to 220°C.

Remember that heating will be much more defined by the thermal mass of the elements and walls of the oven than the air contained therein. If you 'reckon' that the thermal mass of the oven is 2/3 of the 1500W one then you will probably be in luck. If you fork out the $49 and it works, I am sure people would love to know. But personally, I would spring for the extra few bucks for a more powerful unit.

Wow, you want to do double-sided SMD reflow. Hats off to you. I have done some, but have never tried reflowing in the oven. You are correct; in commercial manufacture, components are glued down. I struggle getting solder paste where I want it, in the quantities that I want it!

I see that some people claim to have had success with reflowing one side, then loading and reflowing the second side. This would require you to make a frame for the board, but might be worth a try.

Note that the heating is not all radiant; a lot of it is convection, especially if you follow our tip and rig the fan to run continuously. Shielding one side of the board really won't stop parts reflowing on the bottom as conduction through the board and from the air will still get to reflow temperature.

If you are soldering many TQFP devices, I highly recommend looking on eBay or similar for a low-cost stereo microscope. They cost around $200, but I must say that the day I bought one, I wished that I had it 20 years earlier.

Housing thermocouple for Reflow Oven

The article for the DIY Controller for Solder Reflow Ovens does not contain any information about modifying the oven to house the new thermocouple, or suggestions about protecting the thermocouple cable and/or terminating to suitable connectors.

Before the publication of the April article, I sourced an STC 1000 Thermostat Heating/cooling controller from AliExpress. I installed it in a suitable enclosure with GPOs (no switches) to cater for heating and cooling. I decided to complete the cooling circuit so that the controller can also be utilised if I require it for cooling in the future.

Your article confirmed my idea of utilising the existing wiring and thermostat with the external controller overriding the original thermostat.

I have two suitable toaster ovens (one identical to the one mentioned in your article) which I intend to modify, so suggestions about the placement and installation of the thermocouples would be appreciated.

I don't mind the measurements being out a few degrees due to additional connectors being used between the oven, and patch leads to the controller. I intend to use the oven for baking/curing painted objects. (G. F., Bondi, NSW)

● Phil Prosser responds: my thermocouple goes through the door with enough length of thermocouple wire to let me put the thermocouple near or touching the PCB.

The oven rear wall is in my case is a single layer, so you could drill through it, but I honestly could not see the benefit as I fiddle with the thermocouple wire every time I use it.

Someone fussier than me might want to see the thermocouple lashed down and 'installed'. If they do, then I would go in through the rear panel, but I also feel that this reduces the versatility and accuracy of temperature measurement.

Modifying the Thermal Regulator

I am planning to build a modified version of your March 2020 Programmable Thermal Regulator (siliconchip.com.au/Series/342), similar to what is shown in your Fig 5, to keep a homebrew fermenter box at about 23°C during the summer months. I have two TEC1-12703 Peltiers with a heatsink and a 120mm fan, recovered from a dehumidifier. I have ordered a 120mm water block and radiator to go inside the cabinet.

I will be using your Peltier Driver and Interface shields. I will attempt to convert parts of the Arduino code to BASIC so that I can use a Micromite Mk2 as the controller with four DS18B20s. The Micromite can produce PWM signals up to 500kHz. Do you think a Micromite will be up to the task as Peltier controller? (D. C., Rotorua, NZ)

● The Arduino code is not too busy, so as long as the Micromite can provide those PWM channels in the background to drive everything, you shouldn't have any problems. The HIP4082 has an input threshold of around 2.7V, so should be happy enough to be driven by signals from the 3.3V Micromite.

Most of the parts on the Interface shield have been used in Micromite projects previously, so should be fine, but we would double-check that they do work at 3.3V logic levels. For example, some IR receivers specify a supply voltage above 3.3V.

What the Micromite does lack is a 12V to (5V or 3.3V) regulator; you will need to add a 5V or 3.3V supply or regulator of some sort.

Is swapping Active and Neutral safe?

In Mailbag, on page 6 of the February 2020 issue, Graham Street says he has an older double adaptor which transposes the Active and Neutral pins and claims this is not safe. I wonder why this is so. I grew up in Germany and the power plugs there can be inserted either way – there is no "key" to make sure that the Active is always on the same pin of the plug and it really is no problem.

In fact, it was very handy to have this. As a service technician there I worked on lots of 'hot chassis' TVs; there weren't any that were not! Standard procedure was to check if the chassis was live using the "touch and feel a tingle" method and if it did, just turn the mains plug and bingo, it was OK to work on.

Come to think of it, there are many places where power plugs can be inserted either way. So, what is the point? And why might it be dangerous? (H. L., Dee Why, NSW)

● Countries which use plugs that can be inserted either way around generally require double-pole power switches in their equipment. This ensures that the Active connection is always broken when the device is off. In places like Australia and New Zealand where the two-pin plug is polarised, cheaper single-pole switches can be used to break the Active connection.

If you had a device with a power switch that only isolated Active, and you had Active and Neutral swapped, your whole device was live (connected to Active) when off. That's not usually a problem if its insulation is still good, but if there is an insulation failure, then it's a major hazard.

We wonder what today's occupational health and safety types would say about the "touch and feel a tingle" method of checking for live conductors!

Switching relays with 4G Monitoring Station

Congratulations to Tim on the Remote Monitoring Station in the February 2020 issue (siliconchip.com.au/Article/12335). I will definitely build/experiment with it. I have one query, however. The introduction states that it is able to trigger actions remotely, eg, relay closures. I can find no information regarding this in the article. Will there be a follow-up article, or have I missed something? (C. H., Deep Bay, Tas)

● We left these other actions such as controlling relays as an 'exercise for the reader'. Performing an action like operating a relay will tend to reduce the usefulness of the power saving circuitry (unless it's a latching relay, which adds extra driving complications). Also, such actions will not be remembered when the Arduino goes to sleep (again, unless the relay is latching).

The code for this project has been written to allow user customisation; we expect that the project will be altered by most people. As an example, to switch a digital output (which could be connected to the control pin of a relay module), add the following code to the marked section around line 146:

```
if(strmatch("ACTION",msg))
  {digitalWrite(pin,HIGH);}
```

Where "ACTION" is a keyword received as an SMS from an authorised number and pin/HIGH are the specific pin and level to be set.

If you want to control mains-powered devices, this can easily be done hardware-wise by building our Opto-Isolated Mains Relay (October 2018; siliconchip.com.au/Article/11267). You then just need to connect its input between the pin chosen and GND. For low-voltage (eg, 12V) switching, a pre-built relay shield/module would be cheaper.

Finding articles by category or type

David Maddison's article on Underground mapping, leak detection & pipe inspection (February 2020; siliconchip.com.au/Article/12334) was again very good. However, I suspect there are many similar products which are already widely used here in Australia.

My next-door neighbour provides service and calibration for a range of pipe detection and inspection equipment from a manufacturer in the USA. When the NBN underground cable was being installed in my street, the contractors were using some fancy tools to identify all the underground services.

Still on the topic of Dr Maddison, I think the series of articles he has written about medical technology deserves to be more readily available. Have you ever thought of having lists of articles on particular topics? It would make it easier to research particular subjects.

For example, I like the idea of swallowing a capsule camera instead of having a colonoscopy, as described by him in a past article. But how does a reader find that article? Not easily, I

suggest. Possibly, he could do an update on that topic as I am sure it is rapidly evolving. (L. S., Collaroy, NSW)

● We have lists of articles based on subject categories on our website here: **siliconchip.com.au/Articles/ArticlesByCategory**

If you go down to the entry "25 Medical and Health/Human and Animal" and click on the (currently) "18 features" link to the right, you will see the article you mention at #5.

You could also do a word search on the website for "endoscopic", and you'll find it straight away; only two results are shown for that word. The word search page is at **siliconchip.com.au/Articles/WordSearch** and now that we have all issues back to the start (November 1987) on the website, this searches the whole catalog!

Thanks for your further comments about Dr Maddison's articles. They have been forwarded to him.

Problems with USB Logic Analyser

I bought the USB Logic Analyser (February 2020; **siliconchip.com.au/Article/12342**) but can't get my Windows 10 computer to recognise it. When I plug it into the computer's USB port, the red PWR LED and the blue CH1 LED light momentarily and then go out.

Also, after downloading and installing the sigrok software and using Zadig to install the WinUSB driver, I get the following error when attempting to run PulseView:

Code execution cannot proceed because MSVCR100.dll was not found. Reinstalling the program may fix the problem.

Reinstalling the software does not fix the problem. This error occurs when attempting the installation on machines running Windows 10 and Vista. However, I did manage to install it on a machine running Windows XP! Did you encounter this problem during your development of the article? (J. H., Nathan, Qld)

● Regarding the first problem, it sounds like a bad USB cable. Did you ditch the cable that came with the Analyser and substitute a good one instead?

MSVCR100.dll is part of the 2010 Microsoft Visual C Runtime Library. This is necessary to run most software compiled using the 2010 edition of Microsoft Visual C. As such, it is usually installed along with the software on computers which do not already have this library. It seems like the authors of PulseView have neglected to do this.

The reason it worked on your Windows XP machine is probably because you had previously installed another software package which required this library, and it was installed then.

The following website explains how to install the library, which should allow PulseView to run: **siliconchip.com.au/link/ab28**

Editor's note: J. H. got back to us with the following additional information:

Yes, I replaced the USB cable with my own good cable as per the instructions in your article.

I managed to trace this problem to the USB socket on the device itself. Pin 5, the 5V supply pin, was bent right back and not making contact. By probing it with a long drawing pin, I was able to pull the contact back sufficiently to make contact so that now the device operates properly.

Super 9 FM Receiver coil wire diameter

The parts list for the Super-9 FM Radio (November-December 2019; **siliconchip.com.au/Series/340**) calls for 0.25mm diameter enamelled copper wire for winding T1 and L6, but the winding instructions mention 0.125mm diameter wire for these coils. Please advise which is the correct wire diameter to use. I cannot finish building it until I know. (R. K., Tanilba Bay, NSW)

● You can use 0.25mm diameter wire and wind the required number of turns in two layers, or use 0.125mm diameter wire and wind them in one layer. It is not overly critical.

Super-9 SMD transistor packages

I am constructing the Super-9 FM Receiver, and I have a question regarding the case of the two 30C02CH-TL-E NPN VHF transistors (Q3 & Q4), which I was going to order from Digi-Key.

The Parts List on page 36 of the November 2019 issue describes this transistor being in the SOT-23 package, but on the Digi-Key website, these transistors are described as having an SC-96 case. Could the SC-96 case transistor be used instead of a SOT-23 case transistor? (C. B., Bonville, NSW)

● According to the data sheet supplied via the Digi-Key website, the transistor package is SOT-23, CPH3 or SC-59.

The SC-96 package does exist but is uncommon/deprecated. It's the same width as SOT-23 but slightly taller. See the following PDF for details: **siliconchip.com.au/link/ab29**

The 30C02CH-TL-E from Digi-Key is the correct one to use, even though their package description appears to be in error.

Modifying Micromite projects for 3.5in LCD

I am contemplating building a Micromite LCD BackPack V3 with the 3.5-inch touchscreen (August 2019; **siliconchip.com.au/Article/11764**) and using it with the software from the Boat Computer with GPS (April 2016; **siliconchip.com.au/Article/9887**). My questions are:

1. I presume the larger display demands more memory for its display buffer. Does this consume BASIC program space, data space or something else?

2. The Micromite V3 is available programmed with the Boat Computer software. Will I have to modify the display parameters of the Boat Computer application to utilise all the extra pixel area provided by the larger display?

3. I plan to try to add some functions and change some of the information displays, and also use an LDR to provide automatic dimming of the backlight. How much spare program space (in terms of lines of BASIC code) is available in the 3.5in Micromite V3 after the Boat Computer application is loaded (I know BASIC lines is a subjective measure, but it will give me a better idea than bytes)?

Thank you for producing a magazine that continues providing new ideas and information, along with construction projects that use up-to-date technology. As I am getting on in years, I must say that these days the soldering iron tip shakes rather more than I would like! (D. J., Umina Beach, NSW)

● One thing to point out before you jump in: the Boat Computer was not written with the 3.5in display in mind, so the pre-programmed micro will not work with the 3.5in display.

It surely would be possible to make

it work, but this will probably require going through the BASIC program in detail to do this. It isn't a trivial exercise, as the 2.8in screen (which the Boat Computer is designed for) has a different resolution to the 3.5in display. The program will need to be modified to suit this different resolution, as well as having the new display driver loaded.

So we recommend getting the V2 BackPack kit (which comes with the 2.8in display) unless you are very keen on modifying the software. The fonts have a fixed resolution, so will either appear smaller or need to be modified. With this in mind, we will answer your questions, in case you still want to go ahead with modifying the software to work with the 3.5in display.

1. The display pixel buffer is held on the display module itself, so the Micromite's memory is not affected. There is a slight reduction in program space because the driver for the 3.5in display must be loaded as a library. This takes around 6KB, and the Boat Computer software appears to have 8KB free, so you won't have much left over. You will have to put the Boat Computer software on a diet if you plan to add many features.

2. You will have to load the 3.5in display driver manually (see **siliconchip.com.au/link/ab2b**) and modify the BASIC code to suit the display at every point it uses coordinates to access the screen, which is on the order of 100 lines that need to change.

3. The remaining 2KB of program space will probably allow you to add a few dozen lines. We suspect this will at least be enough to add the auto-dimming feature. The code may also be able to be 'crunched' (have comments/white space removed) to make more space available.

So the short answer is: yes, you can do it, but with a fair amount of work.

Substitutes for brass bolts for Battery Isolator

I want to build the Solid State Dual 12V Battery Isolator (July 2019; **siliconchip.com.au/Article/11699**). I've managed to order everything, mostly from Digi-Key, but it turns out brass bolts are next to impossible to get here in New Zealand.

Is it permissible to substitute stainless steel? I've gotten different answers from different people, so I'm getting confused. I note that car batteries now use lead or stainless. (J. S., via email)

● We don't recommend using stainless steel as its conductivity can be drastically lower than brass; it varies by the exact alloy, but it is generally 1/3 to 1/10 that of brass (which itself is not as good as copper).

Brass screws and nuts are available. Any good specialty fastener shop should have them, as would most ship's chandlers. Here are a couple we found in New Zealand using a web search:

www.bronzeandbrassfasteners.co.nz/products

https://fostersshipchandlery.co.nz/collections/fasteners

There are also plenty available on eBay. A search for "m8 brass" turned up this item: **www.ebay.com.au/itm/132381691222**

That's $3.29 for two M8 x 25mm brass bolts with free delivery (although that might take a few weeks, as they're coming from China). Limiting the origin to Australia still gives plenty of options, although the prices are a bit higher. M8 brass nuts can be found similarly.

Sourcing magnets for flip-dot display

I am building your Flip-dot Message Display (April 2019; **siliconchip.com.au/Article/11520**), but the article doesn't contain any information as to where you got the rare earth magnets. I'm guessing they come from a site like eBay. Can you tell me where you got yours from? (I. H., Glossodia, NSW)

● You are right, we purchased them from eBay, specifically, these: **www.ebay.com.au/itm/272659525722**

They came in a small metallic clamshell case padded with foam. If you are interested in other sellers (eg, in Australia for quicker delivery), then search eBay for "neodymium 3mm 1.5mm". This will reveal several different sellers of suitable magnets.

5-inch screens for Explore 100

I finished building the Micromite Plus Explore 100 board (September-October 2016; **siliconchip.com.au/Series/304**), but when I went to connect it with the 5-inch touchscreen, the screen was a different size, and the holes wouldn't line up.

I did manage to plug them together and power them up, but nothing appeared on the screen.

The touchscreen is 132 x 76mm while the Explore 100 is 133 x 86mm. The touchscreen does measure five inches (127mm) diagonally.

It seems I have the wrong touchscreen. I bought it online, but I don't remember where and no paperwork came with it. Do you have a preferred supplier I could get one from? (T. V., Burpengary, Qld)

● You appear to have purchased an EastRising 5-inch LCD touchscreen. These can be made to work, but they are not a direct plug-in; refer to the comment on page 79 of our September 2016 issue which says:

Note though that the EastRising panel uses non-standard interface connector pin-outs so you must use point-to-point wiring between the Explore 100 PCB and the LCD panel.

You're probably better off using one of the screens that plug straight in. We got ours from two different vendors on AliExpress, and both worked fine. See the links below. You could keep the EastRising display and use it for a different application later.

www.aliexpress.com/item/32659478023.html

www.aliexpress.com/item/32665326615.html

Converting speedo signal between brands

I'm installing a Nissan VQ37VHR motor into the shell of a 1991 Toyota MR2 with the MR2 manual transmission and vehicle speed sensor, as the stock Toyota engine blew up.

I'll be using the Nissan ECU, Nissan ECU harness and Nissan gauges cluster from a 2012-2014 Nissan 370Z V6.

Using the Toyota transmission (and speed sensor on it), do you have a converter to convert the pulse from that Toyota VSS so the Nissan ECU + Cluster can read the data? I prefer to use OEM parts (Nissan or Toyota) to run my setup.

● The only project we have that might do the job is our Speedo Corrector Mk.3 (September 2013; **siliconchip.com.au/Article/4362**). However, we do not know for sure whether the speedometer signal from the Toyota speed sensor will work for the Nissan ECU and instrument cluster, even after passing through the Corrector.

The speedometer corrector does give you the ability to alter the speedo signal frequency, which will likely be required given the differences between the two donor vehicles. It should be suitable, but we can't guarantee it.

By the way, the idea of a V6 MR2 is intriguing. We wonder what all that weight amidships will do to the handling, but it will probably be easier to drive than a turbo MR2. At least the torque delivery will be linear and predictable!

Large scoreboard wanted

I have been an avid subscriber to SILICON CHIP since its inception. I am involved with my local soccer community, and one thing that we don't have (because of cost) is a board with illuminated large numbers to show substitutions (who is coming off, and who is going on) and how many more minutes to be added at the end of a half.

Could this make for a project? I'm sure it would be more cost-effective to build than to buy – suitable displays are currently over $500. (F. W., Mount Gambier, SA)

● We published a design for a Professional Sports Scoreboard in the March-May 2005 issue (siliconchip.com.au/Series/87), and an enhanced version in August 2005 (siliconchip.com.au/Article/3155). There is a Jaycar kit, Cat KC5408 ($499), which is still available. The relatively high cost is no doubt due to the large PCBs required.

That project was mainly designed for basketball, but we think it would work for soccer if you just want to show some numbers that increase when a button is pressed.

Note also that fairly large LED dot matrix displays are available (www.aliexpress.com/item/32616683948.html). A few of those could be combined to make a bigger display.

EPROM programmer not working

Dear Mr Jim Rowe, I have followed you since your days at Electronics Australia with the then-editor, the late Mr Neville Williams, followed by yourself as editor. I consider you a very astute fellow and remember your EDUC-8 very well.

I would have built an EDUC-8, but I was serving in the RAAF at the time and was posted to Malaysia in 1974, servicing the Mirage Cyrano II radar, a hybrid solid-state/vacuum tube design. It used three analog fire control computers. The MTBF was abysmal, and it took 50 personnel to keep them going.

I am a semi-retired electronics tech of a few decades and built your EPROM Programmer (November-December 2002; siliconchip.com.au/Series/110). I have had problems using the software even with updated software from the June 2004 issue (siliconchip.com.au/Article/3571).

It will not program any short address range on the EPROM, even though the software leads you to think it is doing just that. I wish to burn 2KB blocks of the 4KB EPROM. I apply the address range that the software asks for – in this case, 0x0 to 0x7FF (hex) – and it goes ahead; the timing bar moves along supposedly programming, but upon reading the EPROM, nothing has changed, and all locations are still 0xFF.

Also, when a verify command is issued, the software states "verify OK", but obviously it's not. The only way I can burn half the chip is to pad the 2KB hex file with 0xFF to extend the file to 4KB, then program the entire chip. By placing 2KB of 0xFF before the commencement of one file 0x0 to 0x3FF and 2KB after on the next file 0x800 to 0xFFF, I can then achieve burning the two 2KB files on the 2732 4KB EPROM.

This is to provide two monitor programs for a TEC-1 A bare-bones Z80 computer, for training in machine code programming.

Is there some reason I am missing that the programmer with not program blocks of less than 4KB? Am I missing reading something in the documentation? (R. S., Sale, Vic)

● Jim Rowe responds: I could be wrong, but I suspect the programming problems may be due to a PC software-to-programmer communication problem caused by our use of a 'Centronics' parallel interface. We have heard of a few cases of communications problems, apparently caused by some sort of incompatibility between a Centronics port, modern PC BIOSes and Windows.

Ideally, we would develop a new EPROM programmer 'from scratch' with a USB interface, but this would be a major project, and it's doubtful that enough people would be interested to justify it. That's especially true since the very common TL866-style universal USB programmer is fairly affordable, at around $60-70.

Sorry, but all I can suggest at present is that you might try using the Programmer with an older Windows XP or Windows 7 machine, or perhaps find an RS232C/Centronics converter to see if that allows full communication.

From PICAXE to Arduino?

I noticed that Jaycar has stopped selling PICAXE micros. I am always looking for alternatives to the PICAXE range; I don't know if you have tried the Arduino, but I find it has a very steep learning curve. PICAXE is difficult enough, but so far the easiest of the micros I have tried.

Do you know if anyone has any tutorials, preferably in flowchart format, on how to program Atmel AVR devices like the ATega328? (P. H., Narrabri, NSW)

● Jaycar discontinued their PICAXE products a while ago in favour of Arduinos. But Altronics still stocks them; see siliconchip.com.au/link/ab26

We've published many Arduino-based projects; there is no shortage of Arduino tutorials and examples on the web. A good place to start is the Arduino forums at https://forum.arduino.cc/

Arduino is very popular, and there is a large community which appears willing to help via the forum (as noted in our March article on the history of Arduino).

If you strongly prefer BASIC, we suggest that you try the Micromite range. These are much more powerful, CPU-wise, than many Arduinos and PICAXEs. They have many built-in commands to interface with devices such as LCD screens.

The Micromite LCD BackPack V3 from August 2019 (siliconchip.com.au/Article/11764) is easy to build but has a lot of useful features, so that would be a good one to start with.

Alternatively, the Arduino Uno is one of the cheapest ways to get an ATmega328 with a USB-serial interface and pin headers. It doesn't need to be used with the Arduino IDE; it can be programmed in many other ways. While we haven't used it very much, there is a BASIC interpreter for AVR micros call BASCOM – see http://siliconchip.com.au/link/ab27 SC

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Coming up in Silicon Chip

A switchmode replacement for 78xx series regulators

The 78xx series has been around for yonks and is still very useful today. But when there is a high input-output voltage differential, or you need a lot of current, linear regulators generate a lot of heat and have poor efficiency. This small board is a drop-in replacement for a TO-220 package linear regulator. It's up to 96% efficient, needs no heatsinking and has various output voltages from 3.3V to 24V.

Infrared Remote Assistant

Remote controls are convenient and all, but sometimes you have a press a sequence of buttons on different remotes. For example, this may be the case to set up your home theatre system for a particular input. In many cases, other family members may not wish to learn the complicated sequences. The IR Remote Control Assistant can help, by recording and playing back simple or complex sequences of IR codes at the press of a button.

Subtractive Manufacturing

Dr David Maddison details the history of manufacturing techniques involving devices like mills and lathes, through the early years of numerical control and onto the amazing modern CNC machines. These can create a wide array of shapes out of solid blocks of metal, timber, plastics or other materials with extreme precision and virtually no human labour. He also explains quite a few other modern subtractive manufacturing techniques that you may not be aware of.

The Ol' Timer II

We've presented plenty of clocks that give you sub-second accuracy. But sometimes you just need to know whether it's breakfast, lunch or dinner time. This innovative clock is cheap and easy to build, and it spells out the time in an easy-to-understand manner using a series of letters in different colours. Is it eight fifty nine and thirteen seconds? Nah, it's just before nine o'clock.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The July 2020 issue is due on sale in newsagents by Thursday, June 25th. Expect postal delivery of subscription copies in Australia between June 23rd and July 14th.

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Notes & Errata

DIY Oven Reflow Controller, April-May 2020; Low-distortion DDS (May 2019); and DSP Active Crossover & 8-Channel Parametric Equaliser, May-July 2019: The connections between IC11 and IC12 are shown incorrectly on the CPU circuit diagram, but are wired correctly on the PCB. The correct connections are: IC12 pins 2, 5 & 6 go to pins 5, 6 and 4 on IC11 respectively. In other words, SO connects to SDI_SDI2, SI to SDI_SDO2 and SCK to SDI_SCK2.

7-Band Mono or Stereo Equaliser, April 2020: Fig.7(c) is correct for the stereo version, but on the mono version, the negative end of the 100µF capacitor connects to chassis ground rather than V- (these two points are joined via JP2, so the effect is the same).

Tunable HF Preamp with Gain Control, January 2020: the PCB and PCB overlay diagrams (Figs.2(a) & (b) on p42) show T3 rotated 180° compared to the correct orientation. The PCB photos show the correct orientation of T3.

Super-9 FM Radio, November & December 2019: the parts list on p36 of the November 2019 issue called for 1m of 0.25mm diameter ECW for winding T1 & L6 while the winding instructions on p63 of the December issue say 0.125mm diameter. You can use either diameter; if using 0.25mm diameter, wind the first layer on T1 & L6 in two layers. If using 0.125mm diameter, you should be able to fit the turns in one layer.

Arduino-based programmer for DCC Decoders, October 2018: there are some errors in the circuit diagram, Fig.1. The default state of the links between CON1 and CON2/3 have been swapped, ie, pin 6 of CON2 should connect to pin 6 of CON1, and pin 12 of CON3 should connect to pin 12 of CON1. Also, pin 6 of IC1 should directly connect to pin 7, not to pin 4.

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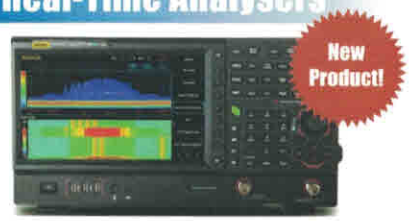

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